MYERS-LAWRENCE DIAGNOSTIC STUDY
MARSHALL COUNTY, INDIANA

EXECUTIVE SUMMARY

The Myers and Lawrence Lake Associations applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement Program for a lake and watershed diagnostic study. The lake associations selected the team of J.F. New & Associates and the Indiana University School of Public and Environmental Affairs to conduct the study. The purpose of the study is to describe the conditions and trends in the Myers-Lawrence watershed, including the lakes, identify potential problems, and make prioritized recommendations addressing these problems. The study team achieved these project goals through historical research of past studies, interviews of current lake residents, and extensive field investigations. This report documents the results of the study.

Myers and Lawrence Lakes lie in the central portion of Marshall County, Indiana. Their combined watershed is small in size (858 acres). Agricultural and residential uses dominate the watershed (45% and 19% respectively). The study identified several areas of concern in the agricultural and residential portions of the watershed where land use practices may be negatively impacting the health of the lakes. Landowners in these areas could implement conservation or Best Management Practices (BMPS) to improve water quality.

The lakes themselves occupy almost 20% of the watershed. When scored using the Indiana Trophic State Index (TSI), both lakes fall in the oligotropic or highest quality category. Lawrence Lake, in particular, possesses good water quality when compared to other Indiana lakes. The Indiana TSI may not be the most appropriate measure of lake health however. Other indictors suggest these lakes may fall in the mesotrophic range. Symptoms of eutrophication are present and appear to be increasing in both lakes. These symptoms include: declining dissolved oxygen concentrations in the hypolimnion, increased phosphorus and ammonia in the hypolimnion, and an extensive rooted plant community. Phosphorus modeling of the lakes and their watershed suggest that a large portion of the phosphorus in the lake originates from internal sources rather than the surrounding watershed.

Problems identified in the study should be addressed by: 1. Developing a comprehensive aquatic plant management program that includes a management technique or combination of techniques designed to remove plant material from the lakes. Mechanical harvesting is one example of such techniques; 2. Considering an alum treatment on both lakes to prevent the release of phosphorus from the sediments; 3. Working with watershed landowners and the NRCS to remove hot spot areas identified in this study from agricultural production, if possible, or establish filter strips in areas where nutrient and sediment runoff is most likely; 4. Implementing Best Management Practices around the shorelines of both lakes including the use of silt fences or other erosion control measures during the construction of new homes along the lakes' shorelines, reduction of fertilizer use on lawns, prohibiting the disposal of lawns wastes in the lakes, and installation of native plants along the shoreline.

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INTRODUCTION

Myers and Lawrence Lakes are situated southwest of Plymouth, Indiana (Figure 1). Specifically, the two lakes are located in Sections 19 and 24, Township 33 North, Ranges 1 and 2 East in West and Central Townships of Marshall County; Latitude: N41^0 18' 6.9" and Longitude: W86^0 21' 17.6 for Myers Lake and Latitude N41^0 17' 53.7" and Longitude W86^0 20' 6.7" for Lawrence Lake. The lakes are the two most eastern lakes of a chain of lakes located in the headwaters of the Harry Cool Ditch watershed. Water from the lakes drains to the Harry Cool Ditch west of Lake Latonka. The Harry Cool Ditch flows west to its confluence with Eagle Creek. Eagle Creek is a tributary of the Yellow River which in turn flows into the Kankakee River.

Both lakes are natural lakes formed during the most recent glacial retreat of the Pleistocene era. The advance and retreat of the Lake Michigan and Saginaw Lobes of a later Wisconsian age glacier as well as the deposits left by these lobes shaped much of the landscape found in northern Indiana today (Homoya et al., 1985). Ice blocks trapped in the deposits left by the retreating glacier melted to create many of the area's natural lakes. Myers and Lawrence Lakes, as well as their watershed, are the result of this geological history.

Myers and Lawrence Lakes are located in the western portion of the Northern Lakes Natural Area (Homoya et al., 1985). The Northern Lakes Natural Area extends east and north from Marshall County and includes much of northeastern Indiana where the majority of natural lakes are located. Natural communities found in the Northern Lakes Natural Area prior to European settlement include bogs, fens, marshes, prairies, sedge meadows, swamps, seep springs, lakes, and deciduous forests. Historically, much of the Myers-Lawrence watershed was likely forested with oak and hickory species. Dominant vegetation around the lake edges likely included red and silver maple, American elm, and green and black ash with more open areas being dominated by cattails, swamp loosestrife, bulrush, marsh fern, and sedges.

Changes in land use have altered the watershed's natural communities described above. Currently, approximately 45% of the land is used for agricultural purposes and 19 % is used for residential uses. Only 14.5 % of the land remains forested. These changes in land use have likely accelerated the natural eutrophication process in Myers and Lawrence Lakes.

Prompted by concerns over their lakes' health, and to get a better understanding of the factors affecting the lakes' health, the Myers and Lawrence Lake Associations applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement Program for a lake and watershed diagnostic study. The lake associations selected the team of J.F. New & Associates and the Indiana University School of Public and Environmental Affairs to conduct the study. The purpose of the study is to describe the conditions and trends in Myers and Lawrence Lakes as well as their watersheds, identify potential problems, and make prioritized recommendations addressing these problems. This report documents the results of the study.

CLIMATE

The climate in Marshall County is characterized as cool and humid with winters that typically provide enough precipitation, in the form of snow, to supply the soil with sufficient moisture to minimize drought conditions when the hot summers begin. The average daily winter temperature is usually around 27 degrees Fahrenheit (-3^{o}C); summer averages are close to 72 degrees (22 ^{o}C). The highest temperature ever recorded was 109 degrees (43 ^{o}C) reached on June 20, 1953. The total annual precipitation averages 38 inches (97 cm), but the total for 1999 fell 2.5 inches (6 cm) short of this average with March, May, July and September being unusually dry months. In typical years, sixty percent of the precipitation falls between April and September, with nearly 40 thunderstorms occurring during these same months. In every 2 out of 10 years, the rainfall between April and September is less than 19 inches (48 cm). April to September of 1999 saw a total of just over 20 inches (51 cm) of precipitation in Marshall County with almost 8 inches (20 cm) of the 20 inches (51 cm) falling in the month of April. The average seasonal snowfall is close to 36 inches (91 cm), and the number of days that snow accumulates and remains on the ground varies greatly each year.

SOIL

The soil types found in Marshall County are a product of the original parent materials deposited by the glaciers that covered this area about 12,000 to 15,000 years ago. The main parent materials include glacial outwash and till, lacustrine material, alluvium, and organic materials. The interaction of these parent materials with the physical, chemical, and biological variables found in the area (climate, plant and animal life, time, and the physical and mineralogical composition of the parent material) formed the soils located in Marshall County today.

Specific soil types found in the Myers-Lawrence watershed are mapped on Figure 2a (Figure 2b displays the legend). Soils in the watershed, and in particular their ability to erode or sustain certain land use practices, can impact the water quality of a lake. For example, highly erodible soils are, as their name suggests, easily erodible. Soils that erode from the landscape are transported to waterways or waterbodies where they impair water quality and often interfere with recreational uses. In addition, such soils carry attached nutrients which further impair water quality by fertilizing macrophytes (rooted plants) and algae. Soils that are used as septic tank absorption fields deserve special consideration as well. The presence of highly erodible soils and the use of septic fields in the Myers-Lawrence watershed are described in further detail below.

Highly Erodible Soils

Three soil types found in the Myers Lawrence watershed are listed as highly erodible soils. These soils are Riddles sandy loam (RsC2, RsD), Wawasee sandy loam (WkC2) and Wawasee sandy clay loam (WmD3). The large majority of land mapped in these soil units is located along the lakes' shorelines. Because of this, special planning and the use of best management practices (BMPs) are needed during residential development projects to ensure minimal erosion.

Highly erodible soils are also mapped in the agricultural areas in the southern portion of the watershed. On agricultural land, the Natural Resources Conservation Service (NRCS) classifies fields in which at least 1/3 of the field is mapped in highly erodible soils as Highly Erodible Land (HEL). (The listing of a field as HEL requires field checking of mapped soil types.) Farm fields mapped as HEL are required to file a conservation plan with the NRCS in order to maintain eligibility for any financial assistance from the U.S. government. Based on the definition above, one field in the Myers Lawrence watershed is mapped as a highly erodible land (Figure 3). This 103.5 acre (42 ha) field accounts for 12% of the watershed.

Septic Field Use

As is common in rural areas, septic tank and septic tank absorption fields are utilized for wastewater treatment in the Myers-Lawrence watershed. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the septic tank effluent to levels that protect the groundwater from contamination. Groundwater is one of the water sources to the lakes. Consequently, the type of soil located adjacent Myers and Lawrence Lakes and the soil's ability to function as a septic tank absorption field will affect the lakes' water quality.

A variety of factors can affect a soil's ability to function as a septic absorption field. Whether or not a soil is typically ponded during a portion of the year has obvious impacts on its ability to serve as a septic field. Frequently ponded soils offer little or no treatment to waste effluent. Untreated effluent is often simply flushed into the lake. Soils located on sloped land may have difficulty treating wastewater as well. Septic fields sited on these soils may require enlarged fields to treat the waste effluent. Soils that have been disturbed through excavation and fill or compaction are also unsuitable for wastewater discharge using soil absorption fields.

In addition, soils with very slow percolation rates are limited in their ability to serve as septic fields. These soils can become clogged due to the high levels of organic material in the septic effluent. Like soils on sloped land, these soil types require very large absorption fields due to the low permeability of the soil. Septic tank absorption fields in these soils with slow percolation rates have a higher rate of failure than fields with higher percolation rates, due to the potential for clogging. Septic field failure, with ponding of wastewater at the surface, may allow the untreated wastewater to flow overland to the lake.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soils series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields on soils in the moderately or severely limited soils generally requires special designs, planning, or maintenance to overcome the limitations. Table 1 summarizes the soil series located adjacent to Myers and Lawrence Lakes in terms of their suitability for use as a septic tank absorption field.

Table 1: Soil Adjacent to Myers-Lawrence Lakes
Source: Soil Survey of Marshall County

Symbol	Name	High Water Table (ft)	Suitability for Septic Tank Absorption Field
Br	Brookston loam	+0.5-1.0	severe; ponding
Gf	Gilford sandy loam	+0.5-1.0	severe; ponding, poor filter
Hp	Houghton muck, ponded	+2-0.5	severe; ponding, percs slowly
RsB	Riddles sandy loam	>6.0	moderate; percs slowly
RsC2, RsD	Riddles sandy loam	>6.0	severe; slope
Wa	Wallkill loam	+0.5-0.5	severe; ponding

Brookston loam (Br), Gilford sandy loam (Gf), and Wallkill loam (Wa) are very poorly drained soils which are frequently ponded. The ponding severely limits these soils for siting septic tank absorption fields. Houghton muck, ponded, (Hp) is a nearly level, very poorly drained soil. This soil is generally covered by shallow water is most of the year, and in some years, it is continually covered. Because of the ponding, this soil is unsuitable for septic tank absorption fields. Fortunately, most of the septic systems in the Myers-Lawrence watershed are not located in these soils.

Riddles sandy loam (RsC2 and RsD) is moderately to strongly sloping well drained soils. Permeability of this soil is moderate. Riddles soil is moderately to severely limited as a site for septic tank absorption fields due to slope. The majority of the soils adjacent and surrounding Myers and Lawrence Lakes are Riddles sandy loam. The steep slopes adjacent to the lake limit these areas for siting septic tank absorption fields. Special designs may need to be implemented when siting new septic fields along the shoreline mapped in these soil units to ensure sufficient treatment of waste effluent.

Pollution from septic tank effluent can contribute to eutrophication, or nutrient enrichment, of the lake. The nutrients present in septic tank effluent can fertilize algae and macrophytes in the lake promoting algae blooms and macrophyte growth. In addition, septic tank effluent potentially poses a health concern for lake users. Swimmers, anglers, or boaters that have body contact with contaminated water may be exposed to waterborne pathogens. Fecal contaminants can be harmful to humans and cause serious diseases, such as infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illness.

Soil Summary

The type of soils in a watershed and the land uses practiced on those soils can affect a lake's health. The Myers-Lawrence watershed contains several highly erodible soil units, both around the shoreline and in the agricultural land south of the lakes. Soils eroding from these areas contribute sediment to the lakes reducing the lake's water quality and interfering with recreational uses of the lakes. Nutrients attached to eroded soils will help fertilize algae and rooted plants. Consequently, conservation methods and best management practices (BMPs) should be utilized when soils are disturbed in these areas. This includes development of shoreline property as well as farming in highly erodible soils.

Soil type should also be considered in siting septic systems. Some soils do not provide adequate treatment for septic tank effluent. Much of the Myers and Lawrence shoreline is mapped in Riddles sandy loam which rates as moderately to severely limited for use as a septic tank absorption field. Poorly designed or poorly located septic systems can add nutrients to a lake, degrade water quality, and potentially affect recreational users' health. Consequently, careful planning is needed to ensure sufficient treatment of septic effluent prior to siting a system along the lakes' shorelines.

WETLANDS

Wetlands provide a variety of functions for an ecosystem. These functions include filtering sediment and nutrients in runoff, detaining water and allowing for groundwater recharge and discharge, and providing nesting habitat for waterfowl and spawning sites for fish. By performing these roles, healthy, functioning wetlands often improve the water quality and biological health of streams and lakes located downstream of the wetlands.

Figure 4a is the U.S. Fish and Wildlife Service's *National Wetland Inventory* (NWI) map for the Myers-Lawrence watershed. (Figure 4b and 4c provides a key to the NWI map.) This map indicates the presence of several wetlands in the watershed, including areas immediately adjacent to the lake. This map is intended only as a guide to potential wetlands in the area. The NWI maps were prepared from high altitude photography and in most cases were not field checked. Because of this, wetlands are sometimes erroneously identified, missed, or misidentified. In addition, academics and governmental agencies do not always agree on the definition a wetland. As a consequence, different governmental agencies have adopted different criteria to identify wetlands. The map in Figure 4a utilizes criteria developed by the U.S. Fish and Wildlife Service which differ from the criteria used by the Corps of Engineers, the agency responsible for regulating the placement of fill in wetlands. The Corps of Engineers has not developed a map locating wetlands on the landscape. They rely on field reconnaissance for determining the location and extent of wetlands.

The NRCS has also developed wetland maps. These maps were created to assist agricultural landowners in determining the type of land use, maintenance, and improvements that are allowed under current regulations. For example, a landowner may maintain drainage tiles on land mapped as Prior Converted (PC), however the landowner may not maintain existing drainage tiles in areas mapped as W or Wetland. Farmed wetlands (FW) are defined as areas that meet the NRCS' definition of a wetland but landowners may maintain drainage to the degree that existed prior to December 23, 1985 and farm those areas when conditions allow. Figure 5 shows two farmed wetlands (FW) in the largest agricultural field south of Myers Lake. These farmed wetlands are well tiled and are currently in agricultural production.

Wetland Summary

Several wetlands are located in the Myers Lawrence watershed. As indicated on Figure 4a many of these wetlands are located along the lakes' shorelines or in drainages leading to the lakes. These wetlands help protect the lakes by filtering sediment and nutrients in runoff preventing deposition to the lakes. Lake residents should continue to protect these wetlands from development. In addition, through an agreement with the landowner, it may be possible to restore the farmed wetlands located in the agricultural land south of Myers Lake. This would restore many of the functions those wetlands originally provided such as filtering sediment and nutrients and slowing runoff by allowing for groundwater recharge and improve the health of Myers and Lawrence Lakes.

NATURAL COMMUNITIES AND ETR SPECIES

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources. Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee the presence of the listed species or that the listed natural area is in pristine condition. To assist users, the database does include the date that the species or special habitat was last observed in a specific location.

Results from the database search for the Myers-Lawrence watershed are presented in Appendix 1. (For additional reference, a listing of endangered, threatened and rare species documented in Marshall County is included in Appendix 2.) Two species, cisco (*Coregonus artedi,* a fish) and pointed campeloma (*Campeloma decisum*, a mussel), are listed in the database as occurring in the Myers-Lawrence watershed. Both are classified as state species of special concern. According to the database, cisco were last observed in 1994 in Lawrence Lake and in 1988 in Myers Lake. The last documented sighting of pointed campeloma was in 1988 in both of the lakes. (The database also notes the presence of the American badger (*Taxidea taxus*) in the nearby Menominee Wetland Conservation Area. However, this area does not lie within the Myers-Lawrence watershed.) Based on field surveys done by the IDNR biologists, it is doubtful if either cisco or pointed campeloma still exist in Myers or Lawrence Lakes.

LAND USE

Figure 6 and Table 2 present land use information for the Myers-Lawrence watershed. Figure 6 was developed by reviewing recent aerial photography followed by ground-truthing. The largest portion of the watershed is in agricultural production (45%). Residential and forested areas account for 19% and 14.5 % of the land use respectively. A much smaller portion of the land is used as open field or pasture.

Based on these percentages, land practices that occur on the agricultural and residential areas are likely to have the strongest impact on the lakes.

Table 2: Land Use In The Myers-Lawrence Watershed

Land use	Area (ac)	Area (ha)	Percentage of watershed
Agricultural	383	155	45%
Residential	166	67	19%
Forested	123	50	14.5%
Pasture/open field	21	8.5	2.5%
Open water	165	67	19%
Total	858	347.5	100%

SHORELINE DEVELOPMENT

Residential development of the shorelines around Myers and Lawrence Lakes likely began in the mid to late 1950's. The Marshall County Historical Society (1986) documents residential development around Lawrence Lake beginning in 1954 when Willard Lawrence sold 12 lots on the north side of the lake. By the late 1960's, approximately 30% of the Lawrence shoreline and approximately 50-60% of the Myers shoreline was developed for residential use. These figures grew to 50% of Lawrence shoreline and 65% of the Myers shoreline by the mid 1980's.

These figures are larger still today. Approximately 61 houses border the Lawrence Lake shoreline. Approximately 10 of these houses are used only seasonally. (Some of these houses are set back from the shoreline by up to 100 feet or approximately 32 meters.) There are 63 year-round residences and 12 seasonal residences located on Myers Lake (Claudia Wayman, personal communication). As is the case around many lakes, the number of year-round residents has increased over the years as people have retired and now live at their cottage/lake house fulltime. In addition, new home development on both lakes was observed during the course of this study. Much of the development is occurring on the south side of Lawrence Lake.

With residential development of the lake, landscaped lawns and seawalls replace natural shoreline vegetation. Currently, seawalls exist on less than 25% of the Myers and Lawrence shorelines. These seawalls consist largely of riprap, railroad ties and concrete, with riprap being the most common type. The bulk of the developed shoreline consists of maintained lawns.

While seawalls provide some temporary erosion control along shorelines, they cannot provide all the functions of a healthy shoreline plant community. Native shoreline communities filter runoff water to the lake, protect the shore from wave action limiting erosion, release oxygen to the water column for use by aquatic biota, and provide food, cover and spawning/nesting habitat for a variety of fish, waterfowl, insects, mammals and amphibians. Removal of the native plant community removes many of these functions.

STORM WATER SAMPLING

<u>Background Information and Methods</u>

While Myers and Lawrence Lakes do not have any natural stream inlets, several areas were identified as potential conduits for concentrated runoff during large storm events. Collection of storm water samples was attempted several times throughout 1999. Most of the potential sites were dry during the typical storm event in 1999. Some of the identified sites likely only have measurable flow during large storm events such as the 10 year or 25 year storm events. This year's unusually dry weather, particularly from May through the end of the year, added to the difficulty in collecting samples. In addition, rain events that did occur this year were small in size (see below).

Storm water samples were collected on two dates: April 22, 1999 and December 14, 1999. On April 22, the Plymouth Power Substation (the recording station for Marshall County) recorded approximately 0.78 inches (2 cm) of rain. Several rain events had occurred within the two weeks prior to April 22 suggesting that the ground was likely saturated at the time of sampling. On December 14, the Substation recorded 0.58 inches (1.5 cm) of rain. Little rainfall occurred prior to this date and given the dry conditions of the proceeding months, it is unlikely that the soil was saturated.

To give some perspective, over a 24 hour period (the interval in which precipitation is recorded at the Substation), approximately 2.36 inches (6 cm) of rain would have to fall to consider the rain event a one year event in Marshall County. Neither 0.78 nor 0.58 inches of rain qualify as a 2 month events. The Substation recorded seven, 24 hour rain events exceeding one inch in 1999. None of these would be considered a one-year storm event, providing more evidence that the rain events in 1999 were unusually small in size.

Despite this, a measurable flow was observed at three of the sampling sites during at least one storm event. On April 22, 1999, samples were collected from sampling Site 1, a channel running from the road encompassing Lawrence Lake to the extreme southeast corner of Lawrence Lake, and Site 2, the culvert under Pine Road located approximately 0.5 miles (0.8 km) north of West 13th Road. Storm water samples were collected again from Site 2 and Site 3, the tile draining the farm field immediately east of Pine Road, on December 14, 1999. (See Figure 7 for the location of Sites 1-3.)

Collected samples were stored on ice and transported the same day to Environmental Health Laboratories (4/22/99 sampling) or EIS Analytical Laboratories (12/14/99 sampling) in South Bend, Indiana. The laboratories analyzed the samples for the following parameters: ammonia, nitrate, total Kjeldahl nitrogen, total phosphorus, total suspended solids, and fecal coliform (E. coli bacterium). The laboratory results are included in Appendix 3.

There are two useful ways to report water quality data in flowing water. *Concentrations* describe the mass of a particular material contained in a unit of water, for example milligrams of phosphorus per liter (mg/L). *Mass loading*, on the other hand, describes the mass of a particular material being carried in the stream per unit of time. For example, a high concentration of phosphorus in a stream with a very little flow can deliver a smaller amount of phosphorus to the lake than a stream with a low concentration of phosphorus but a high flow of water. The total amount (mass) of phosphorus, solids, and bacteria actually delivered to the lake is most important when considering the effects of these materials on a lake. The following table (Table 3) summarizes the results of the storm water sampling using both concentrations and mass loadings.

Table 3: Results From Storm Event Sampling, April 22, 1999 and December 14, 1999

Location	**Site 1**		**Site 2**				**Site 3**	
Date	4/22/99		4/22/99		12/14/99		12/14/99	
Parameter	Conc. (mg/L)	Loading (mg/s)	Conc. (mg/L)	Loading (mg/s)	Conc. (mg/L)	Loading (mg/s)	Conc. (mg/L)	Loading (mg/s)
Ammonia	1.0	70.8	< 0.3	-	< 0.05	-	< 0.05	-
Nitrate	6.19	438.3	11	28.05	3.2	0.768	32	1.9
Total Kjeldahl Nitrogen	4.18	296.0	1.73	4.4	2.0	0.48	1.3	0.0 75
Total Phos.	0.60	42.5	0.20	0.51	0.42	1.0	0.20	0.012
Total Suspended Solids	150	10,620	29	74.0	23	5.5	52	3.0
E. coli*	-	-	-	-	340	816	3300	1,914

Loading rates based on measured discharges of 70801.5 mL/s for Site 1 and 2550 mL/s for Site 2 on 4/22/99 and 240 mL/s for Site 2 and 58 mL/s for Site 3 on 12/18/99.
* E. coli conc. measured in # of colonies/100mL and loading is measured in # of colonies/s.

Results and Discussion

In general, the loading rates of most of the pollutants were low. The low flow rates at the time of sampling likely played a large role in keeping loading rates down. (Please note that loading rates are often given in units of grams/sec rather than mg/sec as shown in the table above.) Considering the small drainage area of Site 1, it appears to be delivering fairly high amounts of phosphorus and total Kjeldahl nitrogen. More sampling is needed to determine whether these delivery rates are maintained at high flows.

One area of concern is the concentration of E. coli found in the December 14 sample at Site 3. The level found in this sample, 3300 colonies/100mL, greatly exceeds the state standard for full body contact (swimming) of 235 colonies/100mL. E. coli is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms are found in water contaminated with domestic wastewater and can present a real threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. Because the sampling point (Site 3) is not downstream of residential development, animal waste, possibly in the form of manure spread as fertilizer, is the most likely source of E. coli in this sample.

It is important to note that the loadings listed above are not actual pollutant loadings to the lakes. Despite having measurable flows at the sampling locations, no flows were noted reaching the lakes at the time of sampling. Sediment and nutrients loads recorded in the table above settled in the channels prior to entering the lakes. Soil and plants in the channels may absorb and immobilize some these pollutants preventing them from ever reaching the lakes. Those not absorbed may enter the lakes during larger rain events. Further sampling, particularly during larger storm events, is needed to better determine the actual loading of pollutants to the lakes.

Determination of actual loading to the lakes would of been difficult at many of the other locations that were identified as potential sampling locations. Most of these locations are culverts which outlet to well vegetated swales and lawns. Vegetated swales and lawns will filter sediments and nutrients from runoff prior to entry to the lake. In these cases a measurement of overland flow would have to be made, which is much more difficult to do, in order to estimate the true loading to the lake.

Summary

The unusual weather of 1999 (lower than average rainfall; small storm events) made the collection of storm water samples in the Myers Lawrence watershed difficult. Of the samples collected, high *E. coli* concentrations were observed in the Site 3 sample. In comparison to Sites 2 and 3, Site 1 recorded higher loading rates, however, no extremely high loading rates were noted at any of the sites. In addition, it was not possible to calculate actual pollutant loadings to the lakes as flows entering the lake were not observed. However, the potential does exist for sediments and nutrients to reach the lake during larger storm events.

In addition to the conduits from which samples were taken, overland flow likely contributes a significant amount of pollutant loading to the lakes. This is common for lakes with small watershed area to lake area ratios. Any management plan for the lakes should include shoreline land use management as well.

Because the sites sampled this year were the only sites to possess measurable flows, they are likely the largest contributors during storm events in any year, rainy or abnormal. Any management effort to curb input of nutrients and sediments from the watershed should focus on these conduits and the portions of the watershed they drain. However, re-sampling these locations during larger rain events is recommended prior to making final decisions on money allocations for lake management projects. The data collected in this study will provide a baseline set for future sampling efforts.

HOT SPOTS

Analysis of soils, land use, and the limited storm water sampling along with site inspections and discussions with lake residents and the Soil and Water Conservation offices in Marshall County have resulted in the identification of four "hot spots" in the watershed (Figure 8). A "hot spot" is an area of the watershed in which the combination of specific soil types, topography, and land uses has created the potential to negatively impact the health of the lake. This negative impact largely results from the increased delivery of sediment and nutrients to the lake. Sediment and nutrient inputs affect a lake's health in a variety of ways. Sedimentation decreases a lake's storage capacity, provides additional substrate for macrophyte growth, interferes with recreational uses, and decreases the aesthetic value of the lake. Nutrient inputs can stimulate algae and macrophyte growth, which in turn interfere with recreational uses and decrease the aesthetic value of a lake. Areas identified as "hot spots" are described in further detail below followed by a discussion of best management practices that may be employed to minimize the impact of these areas to the lakes' ecosystem.

Farm Field Along Pine Road

The farm field along Pine Road south of Myers Lake is the most significant hot spot in the watershed (Figure 8, A). Soils, topographical relief and land practices all play a role in making this field a hot spot. Several highly erodible soils units including Riddles sandy loam and Wawasee sandy loam are mapped on the field (Figure 2a). Combined with the topographical relief, this field qualifies as a Highly Erodible Land (Figure 3). Because of these site characteristics, traditional agricultural practices create a high potential for soil erosion.

Data collected from the storm water samples indicate that sediment and nutrient loss is occurring from this farm. Much of the watershed drained by sample Sites 2 and 3 lies within the farm field along Pine Road. Elevated concentrations of E.coli, suspended solids and nitrate were noted in the samples collected on December 17, 1999, although actual loading rates were low. Again, abnormal rainfall likely played a role in this. Despite the fact that no flow was observed at the culvert across Happy Acres Trail, downstream of the sampling locations, the eroded banks in the channel receiving runoff from the farm field and the fact that wash outs have occurred at the culvert across Happy Acres Trail indicate that the potential exists for delivery of sediment and nutrients from this farm field to Myers Lake. More sampling during periods in which flow to the lake occurs is needed to fully understand the impact of runoff from this farm on Myers Lake.

Northwest Corner of Watershed

The farm field located in the northwest corner of the intersection of Pear and West 12th Roads was identified as another hot spot (Figure 8, B). While this farm field does not possess the same characteristics as the field described above and thus does not have as great of a potential to deliver sediment, nutrients, and pesticides to the lakes, the concentrated flow of water from this field has increased erosion downstream of the field. Runoff from this field is piped under West 12th Road and outlets in the woodlot on the south side of West 12th Road. A large, eroded headcut was noted at the outlet. Water from the outlet has carved a channel through the woodlot along the west side Pear Road to a low spot where it is culverted under Pear Road to Myers Lake. Erosion in this channel provides a continual supply of sediment to west end of the lake. This sediment reduces the lake's storage capacity and aesthetic value and provides a substrate for emergent vegetation which could in turn interfere with recreational uses of the lake. The channel has also flooded Pear Road creating a safety issue for lake residents and visitors.

Farm Field Along West 12th Road

Several lake residents have noted wastewater treatment plant sludge being spread on the agricultural land north of West 12th Road (Figure 8, C). While only a portion of this field lies within the Myers-Lawrence watershed, this practice has the potential to deliver additional nutrients to Myers Lake through a drain tile running under West 12th Road and outletting in a swale leading to Myers Lake. The grassed area at the tile's outlet filters some of the runoff water, but in large rain events it is likely that some nutrients reach the lake. These nutrients will fertilize the plants growing at the lake's edge and the algae growing throughout the water column.

New Home Sites and Existing Homes

While development of a single home site may not have the same impact as land uses discussed above, the cumulative impact of development can contribute observable amounts of sediment to a lake. Construction of new homes on both lakes occurred during the course of this study (Figure 8, D). Because much of the land adjacent to the lakes is mapped in a highly erodible soil unit, these areas have the same potential for soil loss as areas noted on the farm field along Pine Road. Removal of natural vegetation during the development of lakeside land increases the soil loss potential.

Because the Myers-Lawrence watershed is relatively small in size, residential land accounts for a larger percentage of the total watershed compared to lakes with larger watersheds. (See the Lake and Watershed Morphometry Section for more discussion on this.) Consequently, land use activities along the lakes' shorelines can impact the lakes' health as well. Poor siting of septic fields as well as septic field failure can contribute nutrient to the lakes. Overuse of fertilizers and pesticides can lead to increased nutrient loading to the lakes. Disposal of lawn wastes in the lakes also adds to the lakes' nutrient base. Removal of native shoreline vegetation can remove the filtering benefits of these plants and increase erosion potential along the shoreline. Again, it is the cumulative result of the land use by all lake residents that has the largest impact.

WATERSHED MANAGEMENT RECOMMENDATIONS

Several practices are available to manage the "hot spots" listed above. These practices are not mutually exclusive; a combination of them may be utilized to achieve better results.

Conservation Reserve Program

The Conservation Reserve Program (CRP), run by the U.S. Department of Agriculture, is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. Ideal areas for this program include highly erodible lands, riparian zones, and farmed wetlands. In exchange for the plantings, farmers receive cost share assistance for the plantings and annual payments for their land. (See the Additional Funding Section at the end of this document for more details on the Conservation Reserve Program.)

Removing land from production and planting it with vegetation has a positive impact on the water quality of lakes in the watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores for their lakes. (A TSI is an indicator of lake productivity or health. Lower TSI scores indicate lower productivity or generally better water quality. See In-Lake Sampling Section for more details)

Portions of the farm field along Pine Road may be a good candidate for CRP particularly the west central portion. This area is mapped in a hydric soil unit, Renssalaer silt loam. It is also identified as an excavated wetland (PUBGx) on the USFWS National Wetland inventory and a farmed wetland on the NRCS wetland determination map (Figures 4a and 5). This evidence suggests that area was likely a wetland that was drained to allow for agricultural production. Restoring this portion of the parcel to wetland by breaking drainage tiles and planting the area with hydrophytic vegetation would restore the wetland's natural functions. These functions may have included trapping sediment from the surrounding highly erodible soil (filtering nutrients from the runoff) and slowing the release of runoff by retaining the water and allowing for some groundwater recharge. Restoration of these functions would decrease sediment, nutrient, and herbicide/pesticide loadings to Myers Lake.

CRP might also be utilized for the installation of filter strips near the tile inlets in the agricultural field at the intersection of Pear and West 12th Roads and the farm field along West 12th Road. Filter strips in these locations would slow flows and reduce flow volume by increasing infiltration of the runoff. Vegetative strips would also filter sediments, nutrients, and pesticides from the runoff preventing them from reaching the lakes.

Conservation Tillage

Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage requires leaving some portion of the crop on the land after its harvest rather than completely tilling the soil under as is done in conventional tillage. No till is a type of conservation tillage. Depending upon the type of conservation tillage used reported decreases in sediment loading to waterways have ranged from 60 to 98 percent; reduction in phosphorus input range from 40 to 95 percent. Reductions of pesticide loadings have also been reported (Olem and Flock, 1990). In the review of Indiana lakes referred to above (Jones, 1996), lower TSI scores were observed in ecoregions with higher percentages of conservation tillage use. Utilization of conservation tillage at each of the agricultural hot spots identified above would likely improve the water quality in the lakes.

Sediment Traps

While it does not treat the source of the problem, a sediment trap or a series of two or possibly three sediment traps may be installed in the wooded ravine immediately north of the farm field along Pine Road to treat runoff once it has occurred. Sediment traps work by slowing runoff enough to allow sediment particles to settle in the traps. Different sized sediment particles have differing settling rates, with fine silts and clays having the slowest settling rates. Nutrients are typically bound to these smaller sized sediments rather than coarser sediments. As a consequence, any sediment trap should be designed to allow at least partial settling of these smaller sized sediments. Construction of a sediment trap or series of two may be an attractive option for Myers Lake as the property owners of the wooded ravine have already expressed an interest in such work.

Riprap

A variety of erosion control methods have been developed to reduce erosion in channels and waterways. However, due to the steep topographical relief present in the channel adjacent to Pear Road, lining the channel with riprap may be the only feasible solution to the erosion. Riprap would slow the water velocity, reducing the potential for additional erosion and trap coarse sediments preventing their entry to the lake. Additional entrapment of sediments may be possible by constructing a small sediment trap at the bottom of the channel before the water enters the culvert under Pear Road. Water velocities at this point may be too great to allow for enough settling of sediments to make a sediment trap at this location cost effective.

Home Site Erosion Control and Best Management Practices (BMPs)

New home sites

A combination of erosion control methods utilized at new home sites would reduce the amount of sediments and nutrients reaching the lake during development. Silt fencing, or at a minimum, straw bales, should be installed along the lake during new homes development to prevent sediment loss from a site. Silt fences need to be inspected and maintained to ensure effectiveness. Any areas left bare by the development should be seeded as soon as possible with a temporary cover crop of annual grasses to establish a vegetative cover. Lake associations may be able to exert enough pressure on local authorities to pass a local ordinance requiring such erosion control measures during new home construction around lakes. In addition, septic systems at new homes should be designed to work in the strongly sloped soils adjacent to Myers and Lawrence Lakes.

Established home sites

At established home sites, landowners should reduce or eliminate the use of lawn fertilizers. Landowners typically apply more fertilizer to lawns and landscaped areas than necessary to achieve the desired results. Plants can only utilize a given amount of nutrients. Nutrients not absorbed by the plants or soil will runoff into the lake, providing a nutrient base for plants and algae in the lake. At the very minimum, landowners should follow dosing recommendations on product labels. Landowners should also avoid depositing lawn waste such as leaves and grass clippings in the lake as this adds to the nutrient base in the lakes.

In addition to reducing the amount of fertilizer used, landowners should apply phosphorus-free fertilizers. Most fertilizers contain both nitrogen and phosphorus. However, the soil usually contains enough natural phosphorus to allow for plant growth. As a consequence, fertilizers with only nitrogen work as well as those with both nutrients. The additional phosphorus cannot be absorbed by the grass or plants and runs off into the lake. Landowners can have their soil tested to ensure that their property does indeed have sufficient phosphorus and no additional phosphorus needs to be added. The local Soil and Water Conservation District or the NRCS can usually provide information on soil testing.

Lake residents should also consider replacing maintained lawns with native vegetation. Rushes (*Juncus* spp.), sedges (*Carex* spp.), pickerel weed (*Pontederia cordata*), arrowhead (*Sagittaria latifolia*) and lizard's tail (*Saururus cernua*) offer an aesthetically attractive, low profile community in wet areas. A variety of upland forbs and grasses may be planted further inland or drier soils. (Planting of exotic species or submerged vegetation is NOT recommended.) Biologs can be placed along eroded shorelines to prevent further erosion. Restoration of the native shoreline community with these measures would provide shoreline erosion control and filter runoff to the lakes, thus improving the lake's overall health, without interfering with recreational uses of the lake.

LAKE AND WATERSHED MORPHOMETRY

Table 4 summarizes the surface area, volume and other geographic information for Myers and Lawrence Lakes. These data combined with information from the depth-area and depth-volume curves (see below) provide some insight on the physical structure of the lake and the potential impact of the lakes' watershed on the lakes themselves. For example, Myers and Lawrence Lakes have a very small watershed (858 acres or 347.5 hectares) resulting in a small watershed area to lake area ratio (5:1). This is largely the result of the lakes' position in the landscape. Because they are located at the headwaters of a watershed (the Harry Cool Ditch watershed), little area drains to the lakes.

As a comparison, Lake Tippecanoe is situated further downstream in its watershed (the Tippecanoe River watershed). Approximately 115 square miles or 73,600 acres (294.4 square km or 29,800 ha) of land drain to Lake Tippecanoe. The watershed area to lake area ratio for Lake Tippecanoe is approximately 93:1. As a result, Lake Tippecanoe's watershed can potentially exert a greater influence on the health of Lake Tippecanoe compared to the Myers-Lawrence watershed. Conversely, since the shoreline area at Myers and Lawrence accounts for a larger portion of its watershed, shoreline activities may have a greater impact on the overall health of Myers and Lawrence Lakes than the shoreline activities do at Lake Tippecanoe. This means that lake residents have more direct control over their lakes' health than is typical.

Table 4. Physical Characteristics Summary of the Myers and Lawrence Lakes/Watersheds

Characteristics	Myers Lake	Lawrence Lake
Surface Area	96 acres (39 ha)	69 acres (28 ha)
Maximum Depth	59 feet (18 m)	63 feet (19 m)
Mean Depth	28 feet (8.5 m)	20 feet (6 m)
Volume	2,688 acre-ft ($3.3 x 10^6$ m^3)	1,578 acre-ft ($1.9 x 10^6$ m^3)
Legal Lake Level	768.69 feet (234.4 m)	768.69 feet (234.4 m)
Shoreline Length	11,819 feet (3,602 m)	9,301 feet (2835 m)
Subwatershed Size	503 acres (203.5 ha)	355 acres (144 ha)
Combined Watershed Size	858 acres (347.5 ha)	

Combined Watershed:Lakes Area Ratio	Approximately 5:1

Depth-area and depth-volume curves (Figures 9-12) were prepared from the Indiana Department of Natural Resources bathymetric maps (1954 Myers Lake, 1958 Lawrence Lake). The bathymetric maps are shown in Figures 13 and 14. Both Myers and Lawrence Lakes have extensive shallow areas. On Myers Lake, the area in which water depth is less than 10 feet (3.05 m) is approximately 48 acres (19.4 ha) or about 50% of the total lake area. This compares well with Lawrence Lake where approximately 34 acres (13.8 ha) or about 49% of the total lake area is less than 10 feet (3.05 m) deep. The difference between Myers and Lawrence, however, lies in the fact that most of the shallow area in Myers Lake is actually less than 5 feet (1.5 m) deep.

On Myers Lake, Figure 10 shows that volume increases uniformly with depth until about the 44-foot (13.4 m) depth where the steeper curve indicates a greater change in depth per unit of volume. Figure 12 shows a similar shape for Lawrence Lake with the steeper portion of the curve starting at approximately the 45-foot (13.7 m) depth. In other words, the deepest waters of both lakes contain a relatively small volume.

These curves are extremely useful in illustrating important relationships between depth, volume and area. For example, if a particular rooted aquatic plant can grow in water up to ten feet deep, the potential habitat for this plant is approximately 48 acres (19.4 ha) in Myers Lake and 34 acres (13.8 ha) in Lawrence Lake. Knowing this, cost estimates for aquatic plant control or other lake treatments can be easily calculated for a given area and water volume. A lake's physical morphometry affects the fish community structure as well. (More detailed explanations of how the lake's morphometry impacts the biota in the lake are provided in the following sections.)

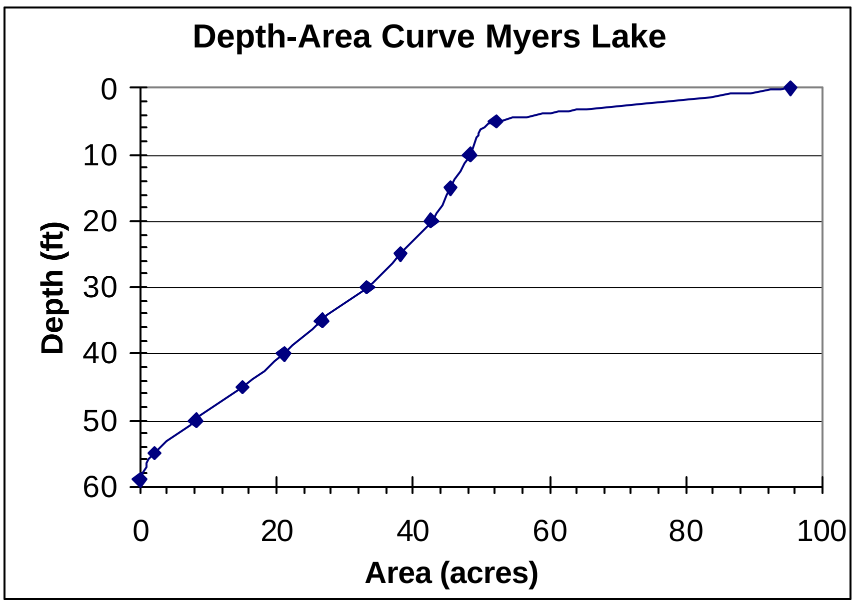

Figure 9. Depth-Area Curve for Myers Lake

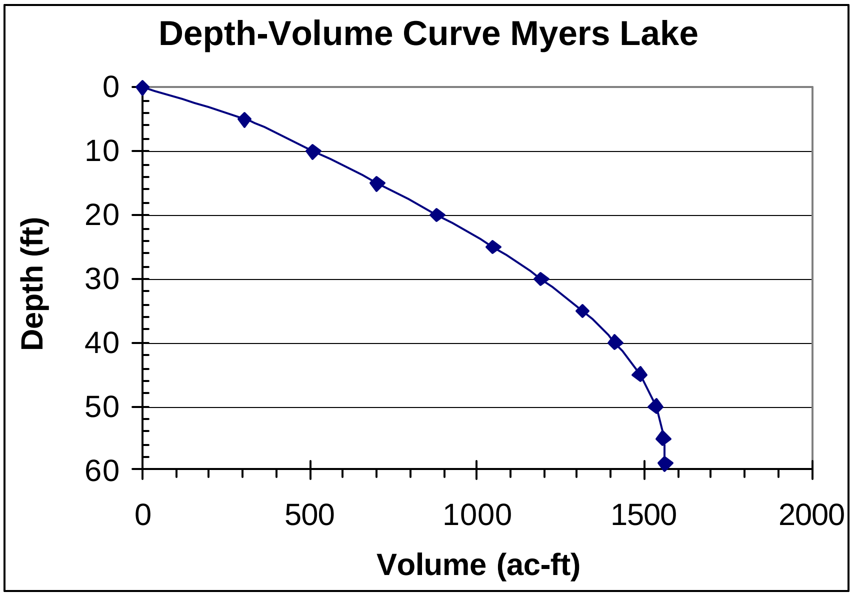

Figure 10. Depth-Volume Curve for Myers Lake

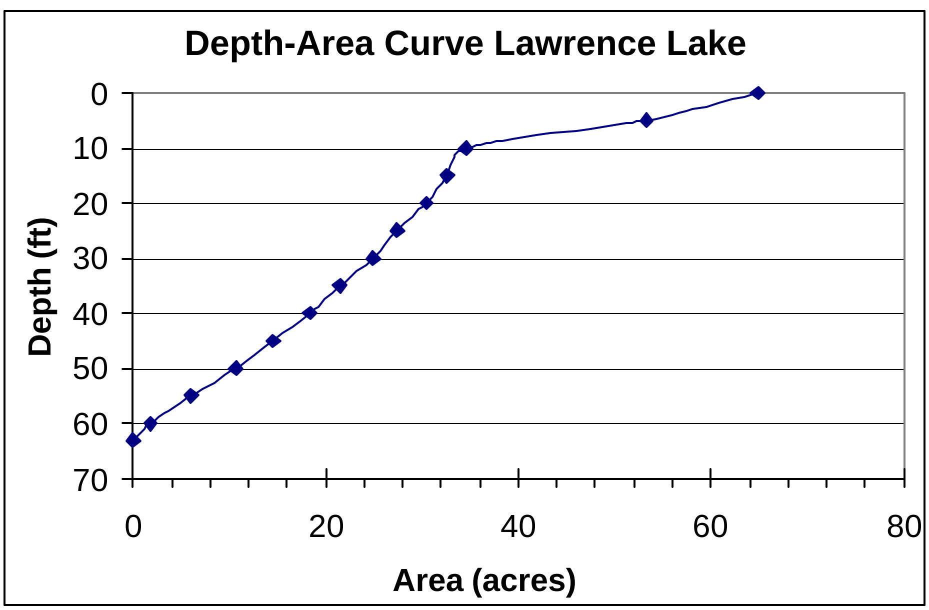

Figure 11. Depth-Area Curve for Lawrence Lake

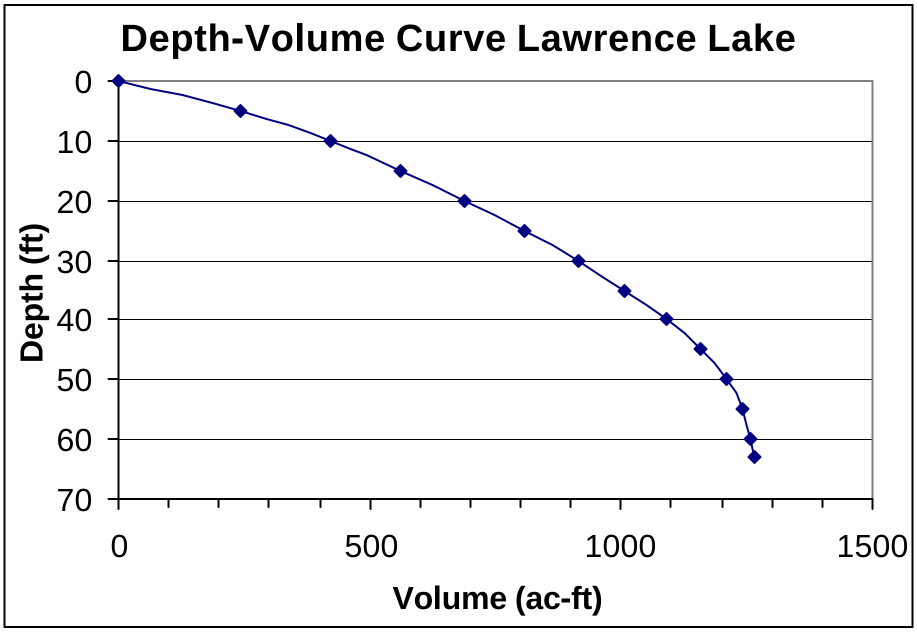

Figure 12. Depth-volume curve for Lawrence Lake

FISHERIES

Myers Lake

The first IDNR fisheries survey of Myers Lake was conducted in 1968 (Robertson, 1968). Two additional studies followed: one in 1976 (Robertson, 1977a) and one in 1985 (Dexter, 1986). An electrofishing survey focusing exclusively on bass was done in 1969.

1968

The 1968 sampling effort consisted of 288 hours of gill netting, 720 hours of trap netting, and 4 seine hauls. 1,100 fish representing 13 species were collected. Bluegill dominated the catch accounting for 33.7% of the total number of individuals. Redear, yellow perch, black crappie and largemouth bass rounded out the catch accounting for 20.5%, 7.7%, 1.5% and 1.4% of the catch respectively. Most of the species exhibited average to below average growth rates. Special concern was expressed over the slow growth rates of the largemouth bass in the lake. IDNR biologists attributed the slow growth rates to the "severe" weed problem and recommended aquatic weed control to improve the Myers Lake fishery.

1976

The IDNR conducted a second survey in 1976. Survey sampling methods included 216 hours of gill netting and 1 hour of electrofishing. The effort yielded a catch of 360 fish from 13 species. Results of the 1976 survey were similar to those from the 1968 survey. Bluegill dominated the catch accounting for 34.7% of the total number of individuals captured followed by lake chubsucker (22.2%), cisco

(8.3%), yellow perch (6.9%), redear (5.8%), black crappie (3.9%), and largemouth bass (2.5%). Bluegill also dominated the catch by weight.

Bluegills exhibited average to below average growth, while yellow perch and redear showed below average growth. 47% of the bluegills collected and 21% of the black crappie collected were of harvestable size. Growth rates of largemouth bass were below average, but they improved from the 1968 sampling.

Based on these results, the study did not make any fisheries management recommendations. The water quality and presence of cisco suggested Myers Lake was capable of supporting a good sport fishery. The study suggested lake residents could treat their pier and dock areas to control local aquatic weed populations if they so desire.

1985

In the 1985 sampling, using gill nets, electrofishing, and trap nets for a combined total of 193 hours of effort, IDNR biologists captured 611 fish from 15 species. Bluegill (35.7%) and lake chubsucker (28.6%) dominated the catch in terms of number of individuals. Lake chubsucker (27.8%) and largemouth bass (17.6%) were the most abundant by weight.

Bluegill growth was above average in the 1985 survey, but fewer harvestable bluegills were collected compared to the 1976 survey. Largemouth bass continued to exhibit slow growth rates, however, the catch per unit effort increased from the 1976 survey. Based on these results, the study concludes that no steps need be taken to improve the Myers Lake fishery.

Summary

Table 5 summarizes the changes in fish community composition based on these three IDNR surveys. The table highlights several aspects of the Myers Lake fishery. In general, the Myers Lake fishery has remained fairly stable over the three decades in which surveys have occurred. Between 13 and 15 species have been collected during each sampling. (Appendix 4 provides a complete list of all species found in the IDNR studies on Myers Lake.) The percentage of lake chubsucker and largemouth bass in the lake's fishery has increased over the past three decades, while the percentage of redear and warmouth has decreased. Bluegill and yellow perch percentages have remained steady.

Bluegill dominate each survey. This is not surprising in light of the physical habitat of Myers Lake. Because a large acreage of the lake is fairly shallow (less than 5 feet or 1.5 m), aquatic plants cover a large portion of the lake. These plants provide excellent cover for smaller fish such as bluegill from larger predators such as largemouth bass.

Past fisheries reports suggest there may be too much cover in Myers Lake. Too much cover typically results in overpopulation of forage fish. Overpopulation, in turn, will strain food resources for the fish. Evidence of overcrowding was noted in the survey in that fewer than fifty percent, and sometimes much less, of the bluegill collected were of catchable size (5.5 inches or more) and collected bluegill often exhibited slow growth rates.

Analyzing the fish community by weight rather than number suggests that overcrowding may not be the reason for the small size and slow growth rates of the bluegill population. In both the 1976 and 1985 survey, the prey to predator ratio by weight is approximately 3:1. Lake fisheries may have prey to predator ratios by weight of up to 8:1 and still be considered self-sustaining (i.e. no stocking required) (Scott Shuler, Aquatic Control, personal communication).

An alternative explanation for the small size and slow growth rates exhibited by the bluegill population in Myers Lake may be the overharvest of large bluegill males. When large bluegill males are overharvested, small males will become sexually mature at a smaller size which in turn slows their growth rate (Beard et al., 1997).

In summary, the Myers Lake fishery is typical of other lakes its size and depth in northern Indiana. The fish population has remained fairly stable over the past three decades. It is likely that cisco have been extirpated from the lake suggesting a decrease in water quality. However, the lake still offers a self-staining population of warm water fish.

Table 5: Summary of Fish Community Composition in Myers Lake

	1967	1976		1985	
Fish	**Relative abundance by number**	**Relative abundance by number**	**Relative abundance by weight**	**Relative abundance by number**	**Relative abundance by weight**
Bluegill	33.7%	34.7%	21.7%	35.7%	16.1%
Lake chubsucker	13.8%	22.2%	18.5%	28.4%	27.8%
Redear	20.5%	5.8%	3.1%	3.0%	2.1%
Yellow perch	7.7%	6.9%	3.8%	4.1%	4.2%
Largemouth bass	1.4%	5.9%	12.0%	8.5%	17.6%
Cisco	-	6.9%	3.8%	-	-
Warmouth	7.7%	3.6%	1.6%	2.6%	2.3%
Black crappie	1.5%	3.9%	3.3%	0.7%	0.4%

Lawrence Lake

The IDNR began documenting the condition of the Lawrence Lake fishery in 1967 (Turner, 1968). Additional fishery surveys were conducted in 1976 (Robertson, 1977b) and 1985 (Robertson and Dexter, 1986). A smaller scale sampling effort was undertaken on November 24 and 25, 1998 (Robertson, 1998).

1967

The 1967 survey consisted of 710 hours of trap netting, 184 hours of gill netting and 2.33 hours of electrofishing. This effort yielded a catch of 672 individual representing 15 species. Bluegill dominated the catch accounting for 28.9% followed by redear (25%), lake chubsucker (15.5%), warmouth (9.4%), pumpkinseed (5.2%), and largemouth bass (4.5%). The bluegill, redear, and largemouth bass exhibited slow growth rates. The bluegill were small in size with only 13% of the bluegill catch being of harvestable size (5.5 inches or more). Redear and yellow perch were small as well.

The IDNR made several recommendations based on the results of the 1967 survey. First, an aquatic plant control program should be initiated to eliminate the excess plant growth in the lake. The study suggests that excessive plant growth has resulted in the overpopulation of forage fish as the plants provide excellent cover from predators. The study also recommends a rotenone treatment with a partial fish kill as its goal. Again the hope is to decrease the abundance of forage fish. Lastly, the study calls for an end to the rainbow trout stocking program due to the lack of interest in it by local residents.

<u>1976</u>

A second comprehensive lake study was conducted in 1976. Survey sampling methods included 216 hours of gill netting and 1 hour of electrofishing. 341 individuals from 15 species were collected during the survey. Species composition changed slightly from 1967. Most noticeable was the increase in the number of black crappie. Bluegill dominated the catch again accounting for 26.4% of the total number of individuals. Other dominant species included lake chubsucker (20.8%), black crappie (10.6%), cisco (8.2%), redear (7.6%), and largemouth bass (5.9%).

Compared to the 1967 survey, more large bluegill were captured. Bluegill 6.0 inches (15 cm) or larger comprised 62% of the bluegill catch. Redear decreased in number from the 1967 survey, but of those caught, 57% were 6.0 inches (15 cm) or larger. Yellow perch were small with only 11.1% of yellow perch catch being of harvestable size. Largemouth bass increased in numbers from the 1967 survey. Based on these results, no fish management recommendations were made in the 1976 survey.

<u>1985</u>

In 1985, the survey consisted of gill netting, electrofishing, and trap netting for a total of 193 hours of effort. The effort returned a catch of 315 individuals from 14 species. More than half of the individuals caught were either lake chubsuckers or bluegills. Cisco, yellow perch, redear, and largemouth bass accounted for 14.6%, 7.9%, 6.0%, and 4.8% of the catch respectively. Ciscoes were the most abundant species by weight (25.9%).

Bluegill numbers dropped compared to the 1976 survey. Those caught exhibited below average growth rates and weights. Approximately 26% of the bluegill catch was of harvestable size declining from 62% in 1976. Fewer largemouth bass were collected in the 1985 as well. Those collected exhibited below average growth rates and weights. In contrast, the number of yellow perch captured increased from the 1976 survey. Those caught were generally small with 32% of the catch being of harvestable size (8.0 inches or more).

The 1985 survey concludes that the Lawrence Lake fishery is generally in good condition. To maintain the fishery, the study recommends continued aquatic weed control and water quality monitoring.

1998

A September 1998 report suggested that cisco could not live in Lawrence Lake because the cold water, high oxygen layer in which this fish live was too small to support any fish (Bob Robertson, personal communication). Concerns over declining water quality and its effect on the lakes' fisheries, specifically the cisco fishery, prompted the IDNR to conduct a sampling trip. The goal of the sampling was to confirm the presence of cisco in Lawrence Lake. Gill nets were deployed during the Thanksgiving week in an attempt to net spawning cisco. Neither the one-hour net deployment nor the overnight deployment resulted in the capture of any cisco. Five other species including golden shiner, perch, bluegill, largemouth bass, and black crappie were caught. While the sampling does not demonstrate that cisco are extirpated from Lawrence Lake, it does not rule that possibility out.

Summary

Table 6 summarizes the changes in fish community composition in Lawrence Lake over the past three decades. In many aspects the Lawrence Lake fishery is similar to that found in Myers Lake. Bluegill populations dominate both fisheries. Redear and warmouth percentages have declined in both lakes while lake chubsucker percentages have increased. The black crappie populations have fluctuated in both lakes. (Appendix 4 provides a complete list of all species found in the IDNR studies on Lawrence Lake.)

The most notable differences in the two lakes is the percentage of bluegills (prey species) in Lawrence is lower than that found in Myers and percentage of predators (largemouth bass and cisco) in Lawrence is greater than that in Myers. The physical difference between the two lakes may account for these observed differences in community structure. As the depth-area curves show (Figures 9 and 11), approximately 43 acres (17.4 ha) of Myers Lake is less than 5 feet (1.5 m) in depth compared to 11.6 acres (4.7 ha) of Lawrence Lake. This suggests that greater vegetation growth is possible in Myers. Increased aquatic vegetation provides increased cover for prey species from predator species and thus may alter the fish community structure.

Table 6: Summary of Fish Community Composition in Lawrence Lake

	1967	**1976**		**1985**	
Fish	**Relative abundance by number**	**Relative abundance by number**	**Relative abundance by weight**	**Relative abundance by number**	**Relative abundance by weight**
Bluegill	28.9%	26.4%	16.0%	21.6%	7.3%
Lake chubsucker	15.5%	20.8%	14.3%	32.4%	21.9%
Redear	25%	7.6%	5.0%	6.0%	4.6%
Yellow perch	4.2%	2.6%	0.9%	7.9%	3.8%

Largemouth bass	4.5%	5.9%	12.0%	4.8%	5.5%
Cisco	-	8.2%	18.9%	14.6%	25.9%
Warmouth	9.4%	3.5%	1.2%	1.3%	0.6%
Black crappie	< 1%	10.6%	8.7%	-	-

AQUATIC PLANT SURVEY

A general macrophyte (rooted plant) survey of Myers and Lawrence Lakes was performed on June 3, 1999. The survey located high density areas of submerged and emergent aquatic vegetation in the lake. On Myers Lake, six of the largest beds of vegetation were mapped, as shown on Figure 15. It should be noted, however, that the majority of the shoreline is vegetated. Five of the largest beds on Lawrence Lake are located on Figure 16. In contrast to the Myers shoreline, vegetation is sparser along the Lawrence shoreline. Before detailing the results of the macrophyte survey, it may be useful to understand the conditions under which lakes may support macrophyte growth and the roles macrophytes play in a healthy, functioning lake ecosystem.

<u>Conditions for growth</u>

Like terrestrial vegetation, aquatic vegetation has several habitat requirements that need to be satisfied in order for the plants to grow or thrive. Aquatic plants depend on sunlight as an energy source. The amount of sunlight available to plants decreases with depth of water as algae,
sediment, and other suspended particles block light penetration. Consequently, most aquatic plants are limited to water depths of 5 or 6 feet (1.5 to 1.8 m), but lakes with greater water clarity have a greater potential for plant growth. Some species such as Eurasian water milfoil can growth in up to 12 feet (3 m) of water.

Related to this is the role lake morphology plays in determining a lake's ability to support aquatic vegetation. Shallower lakes often support more aquatic vegetation than deeper lakes. The depth-area curves show (Figure 9 and 11) show that approximately 43 acres (17.4 ha) of Myers Lake is less than 5 feet (1.5 m) in depth and approximately 11.6 acres (4.7 ha) of Lawrence Lake is less than 5 feet (1.5 m) in depth. This may account for the fact that the Myers shoreline is more vegetated than the Lawrence shoreline.

Aquatic plants also require a steady source of nutrients for survival. Aquatic macrophytes differ from microscopic algae (which are also plants) in their uptake of nutrients. Aquatic macrophytes receive most of their nutrients from the sediments via their root systems rather than directly utilizing nutrients in the surrounding water column. Some competition with algae for nutrients in the water column does occur. The amount of nutrients taken from the water column varies for each macrophyte species. Because most nutrients are obtained from the sediments, it does not necessarily follow that lakes with a high input of nutrients from the waterbody's watershed to the water column will automatically have aquatic macrophyte problems. Other factors, such as those listed above, play a role in limiting or promoting the growth of aquatic macrophytes.

The type of substrate present and the forces acting on the substrate affect a lake's ability to support aquatic vegetation. Lakes that have mucky, organic, nutrient rich substrates have an increased potential for plant growth compared to lakes with gravelly, rocky substrates. In addition, lakes that have significant wave action, disturbing the bottom sediments have decreased ability to support plants. Disturbance of bottom sediment may decrease water clarity limiting light penetration or affect the availability of nutrients for the macrophytes. Wave action may also create significant shearing forces prohibiting plant growth altogether. Boating activity may affect macrophyte growth as well by disturbing bottom sediments.

Both Myers and Lawrence have mucky substrates that are conducive to plant growth. The mucky substrate is natural in these lakes; it is not the result of sedimentation in the lakes. Blatchley (1900) noted the presence of a mucky substrate and marshy shorelines in his survey of Myers and Lawrence. Blatchley also records the presence of a healthy plant community including such species as milfoil (likely northern milfoil as Eurasian water milfoil was not observed in the U.S. until the 1940's), coon tail, pondweed, pickerel weed, pond lilies, bulrushes, and chara.

Ecosystem Roles

Aquatic plants are a beneficial and necessary part of healthy lakes. Plants stabilize shorelines holding bank soil with their roots. The vegetation also serves to dissipate wave energy further protecting shorelines from erosion. Plants play a role in a lake's nutrient cycle by uptaking nutrients from the sediments. Like their terrestrial counterparts, aquatic macrophytes produce oxygen which is utilized by the lake's fauna. Plants also produce flowers and unique leaf patterns that are aesthetically attractive.

Emergent and submerged plants provide important habitat for fish, insects, reptiles, amphibians, waterfowl, shorebirds, and small mammals. Fish utilize aquatic vegetation for cover from predators and for spawning and rearing grounds. Aquatic vegetation serves as substrate for aquatic insects, the primary diet of insectivorous fish. Waterfowl and shorebirds depend on aquatic vegetation for nesting and brooding areas. Aquatic plants such as pondweed, coontail, duckweed, water milfoil, and arrowhead, also provide a food source to waterfowl. Turtles and snakes utilize emergent vegetation as basking sites. Amphibians rely on the emergent vegetation zones as primary habitat.

Survey Results

Myers Lake

Several beds of emerged and submerged vegetation were noted in Myers Lake. These beds are shown on Figure 15. Area 1 occupies the inlet area at the east end of Myers Lake. Vegetation is this area follows the water depth gradient. In the shallowest areas along the shoreline, cattails and purple loosestrife dominate the vegetation. In slightly deeper areas, water willow is the dominant species. Spatterdock with some scattered arrow arum surround the water willow. Submerged beds of Eurasian water milfoil and curly leaf pondweed extend out from the spatterdock, occupying the deeper water.

Areas 2 and 3 are undeveloped areas along the southern edge of the lake where natural shoreline exists. Like Area 1, the vegetation follows the water depth gradient. Silver maple saplings, sandbar willow, soft stem bulrush, water willow, cinnamon fern, purple loosestrife, and cattails dominate the area closest to the shoreline. Patches of spatterdock occupy deeper areas with Eurasian water milfoil dominating the submerged beds. Chara mats dominate some of the shallow water within Areas 2 and 3. Coontail, curly leaf pondweed, white water lilies, white water crowfoot, and duckweed were also noted in Areas 2 and 3.

Area 4 is located at the west end of the lake. A bed of spatterdock occupies the area closest to the shore, while Eurasian water milfoil dominates the deeper water portions of Area 4. Coontail and white water lilies were also observed in Area 4.

Areas 5 and 5a combined form the largest bed of aquatic vegetation on the lake. Area 5 is located largely along the north central shoreline. A portion of Area 5 extends south, nearly spanning the width of Myers Lake. Area 5a extends out from the south central shoreline nearly meeting part of Area 5. The location of these beds corresponds to the shallower areas of Myers (see bathymetric map - Figure 13). Eurasian water milfoil dominates Areas 5 and 5a. Coontail and curly leaf pondweed are scattered throughout the milfoil as well. Patches of spatterdock occupy shallower depths closer to the shore. A portion of the shoreline in Area 5 is undeveloped. Vegetation along that shoreline is similar to the undeveloped portions of shoreline along the southern edge of the lake.

While these areas form the largest beds of aquatic macrophytes, dense macrophyte growth was also observed along much of the shoreline. Eurasian water milfoil typically dominates the areas along the shoreline. Curly leaf pondweed and large leaved pondweed dominate in scattered patches within the Eurasian water milfoil. In addition to these dominants, coontail, naiads, white water crowfoot, white water lilies, eel grass and chair maker's sedge were also noted along the shoreline. Thick chara mats excluded submerged vegetation in a few spots as well. Appendix 5 provides a complete list of macrophytes found in this survey as well as some historical surveys on Myers Lake.

<u>Lawrence Lake</u>

Four major aquatic macrophyte beds were mapped on Lawrence Lake (Figure 16). Area 1 is located at the public boat launch at the west end of the lake. This area was the most diverse bed on the lake. Spatterdock dominates the shallower water closest to the shoreline. Purple loosestrife and pickerel weed were also noted along or near the shore. Curly leaf pondweed, white water crowfoot, slender naiad, flat stem pondweed, large leaved pondweed, northern watermilfoil, Eurasian water milfoil, coontail, white water lilies and duckweed were all observed in and around the spatterdock patches.

Area 2 encompasses the narrow island along the southern edge of the lake. Dominant emergent vegetation on the island includes cattails, purple loosestrife, water willow, willow shrubs, and silver maple saplings. Riverbank grape, iris, dogwood, and soft stem bulrush were also noted on the island. Large patches of spatterdock occupy shallow areas adjacent to the island. A few patches of white water lilies are scattered near the spatterdock. Alternating beds of a variety of pondweeds, including large leaved, flat stem, grass leaved, small and leafy pondweeds, Eurasian water milfoil, coontail and chara mats surround the spatterdock patches in deeper water. Free floating duckweed was observed in Area 2 as well.

Area 3 refers to the channel south of the island. Historically, this channel was likely part of the emergent island forming a wet transitional zone between the upland shore and the lake. Dredging of the channel has created limited boat access for lake residents. Patches of spatterdock some of which are surrounded by white water lilies are scattered throughout the channel. Eurasian water milfoil and coontail dominate the submerged vegetation in the channel. Small portions of the shoreline retain some of their natural vegetation including button bush, bulrush, sweet flag, cattails, pickerel weed, and sedges.

Area 4 is another emergent island located on the east end of the lake. Species composition in this community is very similar to that observed in Area 2. Purple loosestrife, cattails and water willow dominate the island vegetation with cinnamon fern, silver maple saplings, and iris noted in lesser quantities. Large beds of spatterdock jut out from the island to the north. Dominant submerged vegetation in Area 4 includes Eurasian water milfoil, coontail, and white water crowfoot. Duckweed and white water lilies are scattered throughout Area 4.

In addition to these four large beds of vegetation, aquatic vegetation, primarily submerged vegetation, was commonly observed in shallow areas along the shoreline. Typical dominants included Eurasian water milfoil, curly leaf pondweed, large leaved pondweed, and naiads. As observed in Myers Lake, chara mats occasionally excluded submerged vegetation. In general, however, the aquatic vegetation along the Lawrence shoreline is less dense than that observed along the Myers shoreline. Appendix 5 provides a complete list of macrophytes found in this survey as well as some historical surveys on Lawrence Lake.

Aquatic Plant Management

A variety of management techniques have been developed to control aquatic plant growth in lakes. Not all techniques are suitable or even feasible for a given lake. In addition to whether or not a technique is even feasible for a lake, questions such as how much should be spent on aquatic plant treatment and how much control is desired need to be addressed by lake residents prior to developing an aquatic plant management plan. Several management techniques are briefly described below to assist lake residents in choosing the method that best suits their needs. Recommendations specific to Myers and Lawrence Lakes that incorporates analysis of the water quality data will be outlined in the In-Lake Management Recommendations Section of this document.

Chemical control

Herbicides are the most traditional means of controlling aquatic vegetation. Herbicides vary in their specificity to given plants, method of application, residence time in the water and the use restrictions for the water during and after treatments. Herbicides (and algalcides; chara is an algae) that are non-specific and require whole lake applications to work are generally not recommended. Such herbicides can kill non-target plant and sometimes even fish species in a lake. Costs of an herbicide treatment vary from lake to lake depending upon the type of plant species present in the lake, the size of the lake, access availability to the lake, the water chemistry of the lake, and other factors. Typically, in northern Indiana costs for treatment range from $275 to $300 per acre ($680 to $750 per hectare, Jim Donohoe, Aquatic Control, personal communication).

While providing a short-term fix to the nuisances caused by aquatic vegetation, chemical control is not a lake restoration technique. Herbicide and algalcide treatments do not address the reasons why there is an aquatic plant problem and treatments need to be repeated each year to obtain the desired control. In addition, some studies have shown that long-term use of copper sulfate (algalcide) has negatively impacted some lake ecosystems. Such impacts include an increase in sediment toxicity, increased tolerance of some algae species, including some blue green (nuisance) species, to copper sulfate, increased internal cycling of nutrients and some negative impacts on fish and other members of the food chain (Hanson and Stefan, 1984 cited in Olem and Flock, 1990).

Past use on Myers and Lawrence Lakes

Chemical control has been used in the past as the principle means of aquatic plant control in Myers and Lawrence Lakes. Jim Donohoe of Aquatic Control has treated Lawrence Lake for approximately 4 years. Eurasian water milfoil and chara are the primary targets. He applies Reward (diquat) to approximately 4 or 5 acres (1.6 to 2 ha) of the lake. Richard Soper of Pinecrest Industries has conducted the chemical control on Myers Lake and the southern channel on Lawrence Lake. He applies Reward and Cleargate (chelated copper) to approximately 10 to 12 acres (4 to 5 ha) of Myers Lake as well as copper sulfate and Aquathol K and Hydrothal 191 (endothal) to smaller areas. Copper sulfate and Aquathol K and Hydrothal 191 are applied to the southern channel on Lawrence Lake. In the past, Mr. Soper has utilized 2,4 D to control aquatic plants, but it did not achieve the desired results. He attributes this to the low pH and high hardness of the water in Myers Lake. Mr. Soper reports very little change in plant populations over the past 15 years in which he has been treating Myers Lake. He points out that the conditions in Myers, namely a silty substrate, clear water and low nutrient input, are ideal for the growth of Eurasian water milfoil.

Effectiveness

Table 7 is a guide for common herbicides and their effectiveness in treating the dominant macrophytes found in Myers and Lawrence Lakes. This table is general in nature. While the table rates the chemical as effective vs. non-effective, some chemicals are obviously more effective than others. The effectiveness of any chemical often depends upon the water chemistry of the lake to which it is applied. For example, while 2,4 D may typically be effective in controlling Eurasian watermilfoil in other Indiana lakes, it has not been effective in Myers likely due to the lake's low pH and high hardness (Richard Soper, personal communication). Any chemical herbicide treatment program should always be developed with the help of a certified applicator who is familiar with the water chemistry of a targeted lake. In addition, application of a chemical herbicide may require a permit from the Indiana Department of Natural Resources, depending on the size and location of the treatment area. Information on permit requirements is available from the DNR Division of Fish and Wildlife or Conservation officers.

Table 7: Common Herbicides and Their Effectiveness

	Diquat	Endothal	2,4 D	Fluridone
Eurasian water milfoil	M	M	E	E
Curly leaf pondweed	E	E	N	E
Other pondweeds	E	E	-	E*
Coontail	E	E	E	E
Elodea	E	M	N	E
Naiads	E	E*	E*	M

* Depends on species
E = effective
N = non effective
M = mixed results
Table based on information from Olem and Flock, 1990, Westerdahl and Getsinger, 1988, Pullman, 1992 and SePro, 1999.

Mechanical Harvesting

Harvesting involves the physical removal of vegetation from lakes. Harvesting should be viewed as a short-term management strategy. Like chemical control, harvesting needs to be repeated yearly and sometimes several times within the same year. (Some carry-over from the previous year has occurred in certain lakes.) Despite this, harvesting is often an attractive management technique because it can provide lake users with immediate access to areas and activities that have been affected by excessive plant growth. Mechanical harvesting is also beneficial in situation where removal of plant biomass will improve a lake's water chemistry. (Chemical control leaves dead plant biomass in the lake to decay and use up valuable oxygen.)

Macrophyte response to harvesting often depends upon the species of plant and particular way in which the management technique is performed. Pondweeds, which rely on sexual reproduction for propagation, are managed well through harvesting. However many harvested plants, especially milfoil, can re-root or reproduce vegetatively from the cut pieces left in the water. Plants harvested several times during the growing season, especially late in the season, often grow more slowly the following season (Cooke et al., 1993). Harvesting plants at their roots is usually more effective than harvesting higher up on their stems (Olem and Flock, 1990). This is especially true with Eurasian water milfoil and curly leaf pondweed. Benefits are also derived if the cut plants and the nutrients they contain are removed from the lake. Harvested vegetation that is cut and left in the lake ultimately decomposes, contributing nutrients and consuming oxygen.

The cost of the harvester is typically the largest single outlay of money. Depending upon the capacity of the harvester, costs can range from $3,500 to over $100,000 (Cooke et al., 1993). Other costs associated with harvesting include labor, disposal site availability and proximity, amortization rate, size of lake, density of plants, reliability of the harvester, and other factors. Depending upon the specific situation, harvesting costs can range up to $650 per acre ($1,600 per hectare, Prodan 1983, Adams 1983). Estimated costs of the mechanical harvesting program at Lake Lemon in Bloomington, Indiana averaged $267 per acre ($659 per hectare, Zogorski et al., 1986). In general, however, excluding the cost of the machine, the cost of harvesting is comparable to that for chemical control (Cooke et al., 1993, Olem and Flock, 1990). Hand harvesting equipment is also available for smaller areas around piers at a cost of from $50- $1,500 (McComas, 1993).

Drawdown

Lake level drawdown can be used as a macrophyte control technique or as an aid to other lake improvement techniques. This technique requires the ability to discharge water from a lake through an outlet structure or dam. Drawdown can be used to provide access to dams, docks, and shoreline stabilizing structures for repairs; to allow dredging with conventional earthmoving equipment; and to facilitate placement of sediment covers.

As a macrophyte control technique, drawdown is recommended in situations where prolonged (one month or more) dewatering of sediments is possible under conditions of severe heat or cold and where susceptible species are the major nuisances. Eurasian watermilfoil control for example, apparently requires three weeks or longer of dewatering prior to a one-month freezing period (Cooke 1980). Cooke (1980) classifies 63 macrophyte species as decreased, increased, or unchanged after drawdown. One must note the presence of resistant species as well as susceptible species, since resistant species can experience a growth surge after a successful drawdown operation.

Macrophyte control during drawdown is achieved by destroying seeds and vegetative reproductive structures (e.g., tubers, rhizomes) via exposure to drying or freezing conditions. To do so, complete dewatering and consolidation of sediments is necessary. Dewatering may not be possible in seepage lakes.

There are a number of other benefits to lakes and reservoirs from drawdown. Game fishing often improves after a drawdown because it forces smaller fish (bluegill) out of the shallow areas and concentrates them with the predators (bass). This decreases the probability of stunted fish and increases the winter growth of the larger game fish. Drawdown has also been used to consolidate loose, flocculent sediments that can be a source of turbidity in lakes. Dewatering compacts the sediments and they remain compacted after reflooding (Born et al. 1973 and Fox et al. 1977).

A final consideration in implementation of lake level drawdown is season; winter or summer are usually chosen because they are most severe. According to Cooke (1980), “it is not clear whether drawdown and exposure of lake sediments to dry, hot conditions is more effective than exposure to dry, freezing conditions.” One factor to consider is which season is most rigorous. Advantages of winter drawdown include less interference with recreation, ease of spring versus autumn refill, and no invasion of terrestrial plants. Sediment dewatering is easier in summer.

In Murphy Flowage, a 180 acre (73 ha) reservoir in Wisconsin, a five foot drawdown from mid-October to March greatly reduced the presence of aquatic macrophytes the following growing season. Milfoil was reduced from 20 to <2.5 acres (8 ha to <1 ha), spatterdock was reduced from 42 to 12.5 acres (17 ha to 5 ha), and pondweeds were reduced from 114 to 7.5 acres (46 ha to 3 ha) (Beard 1973).

Drawdowns are not possible on all lakes. In lakes and reservoirs that do not have legal lake levels, manipulation of water level is possible without obtaining permission from regulatory agencies. In Myers and Lawrence, a legal lake level of 768.69 was established by the court system in 1949. Any effort to raise or lower the lake level requires that the legal level be changed. This process can be quite time consuming taking up to a year for a decision to be made. In addition, drawdowns are not physically practical on lakes that lack water control structures, as is the case on Myers and Lawrence Lakes. On lakes where drawdowns are feasible, however, they offer a low cost management technique that does not require the introduction of chemicals or machinery.

<u>Biological control</u>

<u>*Grass carp*</u>

Grass carp are the most well known species used for biological control of aquatic plants. Grass carp are an exotic fish species brought to this country from Malaysia. These carp feast on a wide range of aquatic weeds; *Elodea* spp. and pondweeds are among their favorites. Unfortunately, grass carp do not like milfoil and will only eat milfoil when its favorite foods are depleted. Over the course of time, grass carp typically will devour all the plants in a lake, leaving none for fish habitat or bank/substrate stabilization. In addition, grass carp may negatively alter resident fish communities, increase nutrient release from sediments promoting algal blooms and increase the turbidity of lakes. For these reasons, the use of grass carp in public waters is banned in 18 states including Indiana. Carp stocked in private ponds must be certified as geneically triploid and must have no possible access to other waterways.

<u>*Insects*</u>

The use of specific insect species in controlling aquatic plant growth has been investigated as well. Much of this research has concentrated on aquatic plants that are common in southern lakes such as alligator weed, hydrilla and water hycinth. Cooke et al. (1993) also points to four different species that may reduce Eurasian water milfoil infestations: *Triaenodes tarda*, a caddisfly, *Cricotopus myriophylii*, a midge, *Acentria nivea*, a moth and *Litodactylus leucogaster*, a weevil.

Eurasian water milfoil

Recent research suggests another alternative: *Euhrychiopsis lecontei*, a weevil. *E. lecontei* has been implicated in a reduction of Eurasian water milfoil in several Northeastern and Midwestern lakes (EPA, 1997). *E. lecontei* weevils reduce milfoil biomass by two means: one, both adult and larval stages of the weevil eat different portions of the plant and two, tunneling by weevil larvae cause the plant to lose buoyancy and collapse, limiting it ability to reach sunlight. Techniques for rearing and releasing the weevil in lakes have been developed and under appropriate conditions, use of the weevil has produced good results in reducing Eurasian water milfoil.

Cost effectiveness and environmental safety are among the advantages to using the weevil rather than traditional herbicides in controlling Eurasian water milfoil (Christina Brant, EnviroScience, personal communication). Cost advantages include the weevil's low maintenance and long-term effectiveness versus the annual application of an herbicide. In addition, use of the weevil does not have use restrictions that are required with some chemical herbicides. Use of the weevil has a few drawbacks. The most important one to note is that reductions are seen over the course of several years, however, so lake residents need to be patient.

Purple loosestrife

Biological control may also be possible for controlling the growth and spread of the emergent purple loosestrife. Like Eurasian water milfoil, purple loosestrife is an aggressive non-native species. Once purple loosestrife becomes established in an area, the species will readily spread and take over the habitat, excluding many of the native species which are more valuable to wildlife. Conventional control methods including mowing, herbicide applications, and prescribed burning have been unsuccessful in controlling purple loosestrife.

Some control has been achieved through the use of several insects. A pilot project in Ontairo Canada reported a decrease of 95% of the purple loosestrife population from the pretreatment population (Cornell Cooperative Extension, 1996). Four different insects were utilized to achieve this control. These insects have been identified as natural predators of purple loosestrife in its native habitat. Two of the insects specialize on the leaves defoliating a plant (*Gallerucella calmariensis* and *G. pusilla*), one specializes on the flower, while one eats the roots of the plant (*Hylobius transversovittatus*).

Like biological control of Eurasian water milfoil, use of purple loosestrife predators offers a cost-effective means for achieving long term control of the plant. Complete eradication of the plant cannot be achieved through use of a biological control. Insect (predator) populations will follow the plant (prey) populations. As the population of the plant decreases, so will the population of the insect since their food source is decreasing.

<u>Bottom covers</u>

Bottom shading by covering bottom sediments with fiberglass or plastic sheeting materials provides a physical barrier to macrophyte growth. Buoyancy and permeability are key characteristics of the various sheeting materials. Buoyant materials (polyethylene and polypropylene) are generally more difficult to apply and must be weighted down. Sand or gravel anchors can act as substrate for new macrophyte growth, however. Materials must be permeable to allow gases to escape from the sediments; gas escape holes must be cut in impermeable liners. Commercially available sheets made of fiberglass-coated screen, coated polypropylene, and synthetic rubber are non-buoyant and allow gases to escape, but cost more (up to $66,000 per acre or $163,000 per hectare for materials, Cooke and Kennedy, 1989). Indiana regulations specifically prohibit the use of material as a base for beaches.

Due to the prohibitive cost of the sheeting materials, sediment covering is recommended for only small portions of lakes, such as around docks, beaches, or boat mooring areas. This technique may be ineffective in areas of high sedimentation, since sediment accumulated on the sheeting material provides a substrate for macrophyte growth. The IDNR requires a permit for any permanent structure on the lake bottom, including anchored sheeting.

Dredging

Dredging is occasionally used as a means to control aquatic plant growth. Dredging may control aquatic vegetation by two means. First, it removes aquatic vegetation. Second, it may prevent the re-establishment of vegetation by removing the substrate in which vegetation flourished and deepening the lake to a depth at which the sunlight penetration may be too limited or water pressure may be too great to allow for plant growth. Any dredging activities in a fresh water public lake will require permits from the Corps of Engineers, the Indiana Department of Environmental Management (IDEM), and IDNR. Dredging operations are fairly costly with prices ranging from $15,000 to $20,000 per acre ($37,000 to $49,400 per hectare, Jeff Krevda, Dredging Technologies, personal communication). This estimate excludes the cost of transportation to a disposal site and purchasing the disposal site if one is not available for free.

Dredging has several negative ecological impacts associated with it. For example, habitat for many aquatic insects (the macrophytes and top portion of the lake sediment) is removed along with the insects. These insects serve as an important food source to fish and their removal may harm a lake's fishery. In addition, mechanical dredging resuspends nutrient rich sediments which could lead to algae blooms. Because of these reasons and given the amount of material that would have to be removed in order to achieve the desired effect in Myers Lake, dredging is not recommended as a cost effective means of aquatic plant control.

Discussion and Summary

A macrophyte survey was conducted on Myers and Lawrence Lakes on June 3, 1999. In general, both lakes are dominated by curly leaf pondweed and Eurasian water milfoil, which are not native to Indiana lakes. These species typically grow in dense mats excluding other plants and offering little if any habitat potential for aquatic fauna.

While curly leaf pondweed and Eurasian water milfoil dominate the lake macrophyte communities, they have not completely eliminated native plants. Spatterdock, pickerel weed, coontail, eel grass and pondweeds are typical natives in the Northern Lakes Natural Region (Homoya et al., 1985) Healthy individuals of these species were noted in both lakes. In addition, patches of large-leaved pondweed, which provides excellent fish habitat (Curtis, 1998), exist in both lakes. Lastly, small pondweed (*Potamogeton pusillus*) which is a state rare species was noted in Lawrence Lake. A complete list of species found in both lakes during this survey and in past surveys conducted by the IDNR is included in Appendix 5.

It is important to note that the presence of curly leaf pondweed and Eurasian water milfoil is typical for northern Indiana lakes. These species were observed in every lake in Marshall County in 1997 (White, 1998a). Moreover, their absence was only documented in seven lakes in 15 of the northern counties in Indiana. These 15 counties include all of the counties in northeastern Indiana where most of Indiana's natural lakes are located. Of the northern lakes receiving permits to treat aquatic plants in 1998, Eurasian water milfoil was listed as the primary target in those permits (White, 1998b).

Based on the results of the survey, the development of an aquatic plant management plan is recommended for Myers and Lawrence Lakes. Any management plan should target reductions in curly leaf pondweed and Eurasian water milfoil populations. Reducing these populations will allow for the establishment of native, less aggressive macrophytes that provide many of the functions of a healthy lake ecosystem. More specific management recommendations for Myers and Lawrence Lakes incorporating the data collected during the in-lake sampling and modeling are outlined in the In-Lake Management Recommendations Section of this document.

HISTORICAL WATER QUALITY INFORMATION

A search of published information on Myers and Lawrence Lakes identified several reports including several Indiana Department of Natural Resources (IDNR) fisheries surveys dating back to 1968, a lake assessment conducted by the Indiana State Board of Health in the early 1970s, additional lake assessments conducted by the Indiana Department of Environmental Management's (IDEM) Clean Lakes Program, and records from volunteer lake monitors. (The volunteer monitoring program is also part of the Indiana Clean Lakes Program.) Citizen volunteer monitors collected Secchi disk transparency on Myers Lake continuously from 1990 through 1999, with the exception of 1992 and 1996. On Lawrence Lake, a citizen volunteer monitor collected Secchi disk transparency from 1990 through 1993. Since that time, there has not been a citizen volunteer collecting transparency data on Lawrence Lake.

Tables 8 and 9 present a summary of selected historic water quality parameters (including this study) for Myers and Lawrence Lakes respectively. Because of the large volume of data, Secchi disk depths collected by volunteer monitors on Myers Lake is listed in Appendix 6. On both lakes, Secchi disk transparency was variable as expected, but there was a general trend of decreasing transparency over time (Figures 17 and 18).

In Myers Lake, total phosphorus (TP) concentrations in the surface waters (epilimnion or 'epi') have declined over time but the small number of samples (4 over 26 years) are too few to ascribe trends. TP concentrations in the bottom waters (hypolimnion or 'hypo') were quite high but they too appear to be declining. In Lawrence Lake, TP concentrations have varied somewhat over time. TP concentrations epilimnion were relatively low but the TP concentrations in the hypolimnion were quite high. In both lakes, a consistent pattern existed of lower phosphorus concentrations in the surface waters and higher concentrations in the bottom waters. That suggests that phosphorus was being released from the sediments during stratified conditions.

Table 8. Summary of Historic Data for Myers Lake

DATE	SECCHI DISK (ft)	pH	TP (epi) mg/L	TP (hypo) mg/l	DATA SOURCE
6/10/68	15.6	8.5			Robertson, 1968
8/1/73	11.7		0.060		ISBH, 1986
6/1/76	15.3	9.0			Robertson, 1977
6/11/85	9.0	8.5			Dexter, 1986
8/14/89	9.8	8.3	0.026	0.267	CLP, 1989
7/31/95	11.20	8.3	0.017	0.241	CLP, 1995
8/12/99	4.59	8.4	0.028	0.108	Present study

Table 9. Summary of Historic Data for Lawrence Lake

DATE	SECCHI DISK (ft)	pH	TP (epi) mg/L	TP (hypo) mg/l	DATA SOURCE
8/8/67	14.0	8.0			Turner, 1968
7/1/73	13.0		0.020		ISBH, 1976
7/1/76	20.0	8.5			Robertson, 1977
6/11/85	9.0	8.0			Robertson and Dexter, 1986
8/14/89	6.9	7.3	0.036	0.280	CLP, 1989
6/10/90	4.0				Volunteer monitor
6/24/90	4.5				Volunteer monitor
7/8/90	4.8				Volunteer monitor
7/24/90	5.0				Volunteer monitor
8/11/90	8.0				Volunteer monitor
8/26/90	8.0				Volunteer monitor
9/10/90	8.0				Volunteer monitor
10/2/90	8.0				Volunteer monitor
5/11/91	5.0				Volunteer monitor
6/19/91	8.0				Volunteer monitor
7/5/91	9.0				Volunteer monitor
8/12/91	11.0				Volunteer monitor
9/11/91	11.0				Volunteer monitor
5/16/93	6.5				Volunteer monitor
7/31/95	11.2	8.2	0.010	0.197	CLP, 1995
8/12/99	9.5	8.0	0.029	0.248	Present study

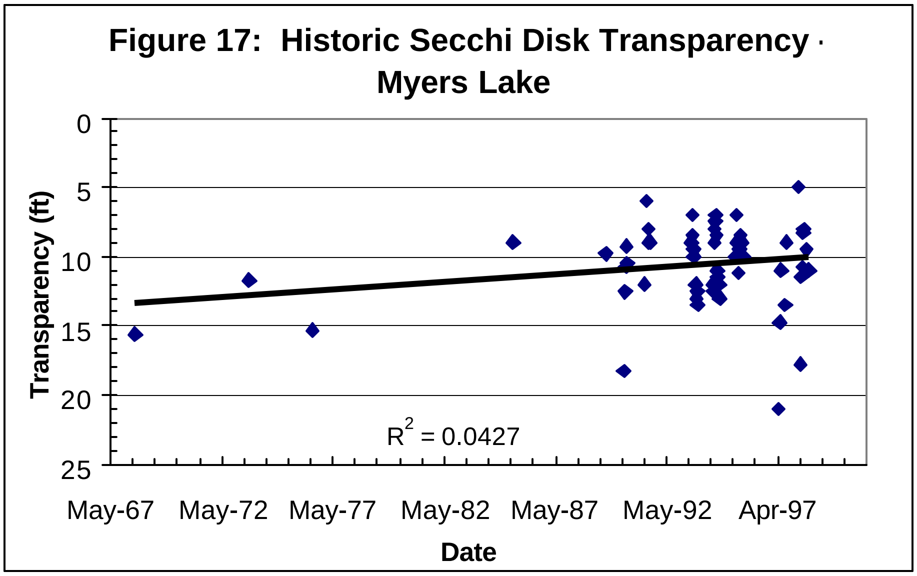

Figure 17. Secchi disk transparency data trend for Myers Lake.

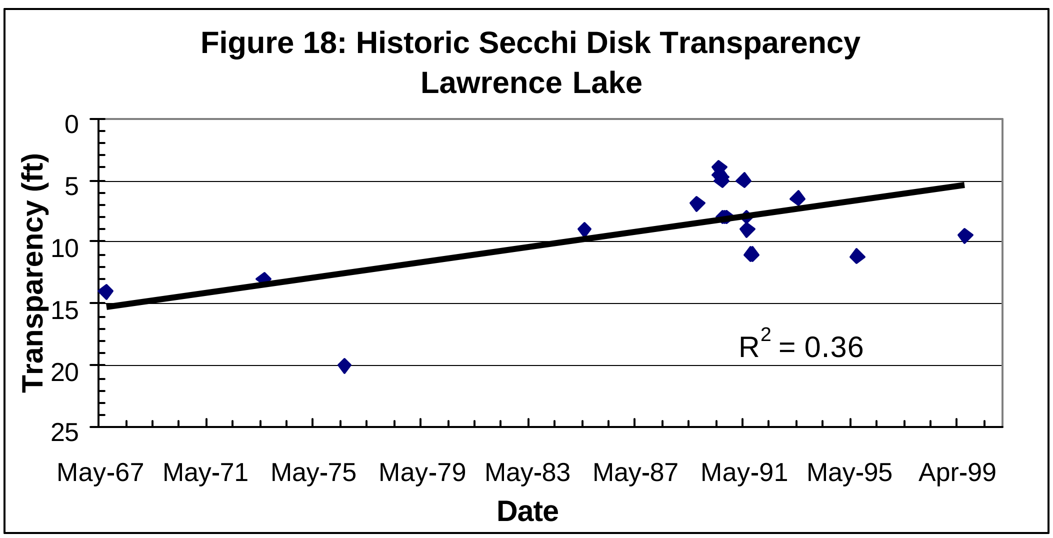

Figure 18. Secchi disk transparency data trend for Lawrence Lake.

Two previous comprehensive lake assessments were conducted in 1989 and 1995 under the auspices of the Indiana Clean Lakes Program. Results from these two assessments for both lakes are given in Tables 10-13 as a comparison to data collected during this study. As part of these assessments, trophic state index (TSI) scores were determined using the Indiana Trophic State Index. Based on these TSI scores, both Myers and Lawrence Lakes fall between the mesotrophic and oligotrophic categories. TSI scores and their significance will be discussed in further detail in the In-Lake Sampling Section of this document.

Table 10. Water Quality Characteristics of Myers Lake on 8/14/89

Parameter	Epilimnetic Sample (1m)	Hypolimnetic Sample (3m)	Indiana TSI Points (based on mean values)
PH	8.3	6.8	-
Alkalinity	169 mg/L	215 mg/L	-
Conductivity	800 μmhos	750 μmhos	-
Secchi Disk Transp.	3.0 meters	-	0
Light Transmission @ 3 ft	45 %	-	3
1% Light Level	19 feet	-	-
Total Phosphorus	0.026 mg/L	0.267 mg/L	3
Soluble Reactive Phos.	0.007 mg/L	0.243 mg/L	3
Nitrate-Nitrogen	2.121 mg/L	2.303 mg/L	4
Ammonia-Nitrogen	0.034 mg/L	1.341 mg/L	3
Organic Nitrogen	1.121 mg/L	0.754 mg/L	3
Oxygen Saturation @ 5 ft.	102.8%	-	0
% Water Column Oxic	56 %	-	2
Plankton Density	16,345 per L	-	5
Blue-Green Dominance	Yes	-	10

TSI Score 36

Table 11. Water Quality Characteristics of Myers Lake on 7/31/95

Parameter	Epilimnetic Sample (1m)	Hypolimnetic Sample (3m)	Indiana TSI Points (based on mean values)
pH	8.3	6.5	-
Alkalinity	154 mg/L	179 mg/L	-
Conductivity	432 μmhos	353 μmhos	-
Secchi Disk Transp.	3.4 meters	-	0
Light Transmission @ 3 ft	29 %	-	4
1% Light Level	15 feet	-	-
Total Phosphorus	0.017 mg/L	0.241 mg/L	3
Soluble Reactive Phos.	0.005 mg/L	0.197 mg/L	3
Nitrate-Nitrogen	0.022 mg/L	0.022 mg/L	0
Ammonia-Nitrogen	0.018 mg/L	0.926 mg/L	2
Organic Nitrogen	0.519 mg/L	0.463 mg/L	0
Oxygen Saturation @ 5 ft.	102%	-	0
% Water Column Oxic	100%	-	0
Plankton Density	18,300 per L	-	3
Blue-Green Dominance	Yes	-	10

TSI Score 25

Table 12. Water Quality Characteristics of Lawrence Lake on 8/14/89

Parameter	Epilimnetic Sample (1m)	Hypolimnetic Sample (3m)	Indiana TSI Points (based on mean values)
pH	7.3	6.5	-
Alkalinity	174 mg/L	212 mg/L	-
Conductivity	330 μmhos	280 μmhos	-
Secchi Disk Transp.	2.1 meters	-	0
Light Transmission @ 3 ft	40 %	-	3
1% Light Level	14 feet	-	-
Total Phosphorus	0.036 mg/L	0.280 mg/L	3
Soluble Reactive Phos.	0.003 mg/L	0.243 mg/L	4
Nitrate-Nitrogen	2.294 mg/L	3.367 mg/L	3
Ammonia-Nitrogen	0.043 mg/L	2.196 mg/L	3
Organic Nitrogen	1.089 mg/L	1.467 mg/L	3
Oxygen Saturation @ 5 ft.	95.0 %	-	0
% Water Column Oxic	50 %	-	2
Plankton Density	-	-	0
Blue-Green Dominance	Yes	-	10

TSI Score 33

Table 13. Water Quality Characteristics of Lawrence Lake on 7/31/95

Parameter	Epilimnetic Sample (1m)	Hypolimnetic Sample (3m)	Indiana TSI Points (based on mean values)
pH	8.2	6.7	-
Alkalinity	149 mg/L	191 mg/L	-
Conductivity	431 μmhos	320 μmhos	-
Secchi Disk Transp.	3.4 meters	-	0
Light Transmission @ 3 ft	25 %	-	4
1% Light Level	21 feet	-	-
Total Phosphorus	0.010 mg/L	0.197 mg/L	3
Soluble Reactive Phos.	0.005 mg/L	0.166 mg/L	3
Nitrate-Nitrogen	<0.022 mg/L	<0.022 mg/L	0
Ammonia-Nitrogen	<0.018 mg/L	1.285 mg/L	3
Organic Nitrogen	0.554 mg/L	0.780 mg/L	2
Oxygen Saturation @ 5 ft.	101.3 %	-	0
% Water Column Oxic	100 %	-	0
Plankton Density	4886 per L	-	1

Blue-Green Dominance	Yes	-	10

TSI Score 26

Several dissolved oxygen profiles (D.O.) exist for Myers and Lawrence Lakes (Figures 19 and 20, respectively). Although the profiles measured every five feet by IDNR went no deeper than 40 feet (13 meters), they show that more oxygen was present in the water in the period from 1967 to 1985 than the period from 1989 to 1995. In the latter profiles for Myers Lake, there was virtually no D.O. in the water below 26 feet (8 meters), but D.O. concentrations ranged from 4 to 8 mg/L at 26 feet (8 meters) in the earlier IDNR studies. On Lawrence Lake, the latter profiles show D.O. absent from water below 23 feet (7 meters) where D.O. concentrations ranged from 6 to 12 mg/L in the earlier studies. The higher D.O. concentrations found in the IDNR studies may have been influenced by the earlier sample date (June), when the lake might not have been as strongly stratified. The D.O. data suggest that a substantial amount of organic matter has been deposited on the lake bottom since the early 1980s. This material represents a biochemical oxygen demand (BOD). In other words, bacterial organisms consume dissolved oxygen as they decompose this organic matter. The source of this decaying organic material is likely the abundant rooted aquatic plants in both lakes.

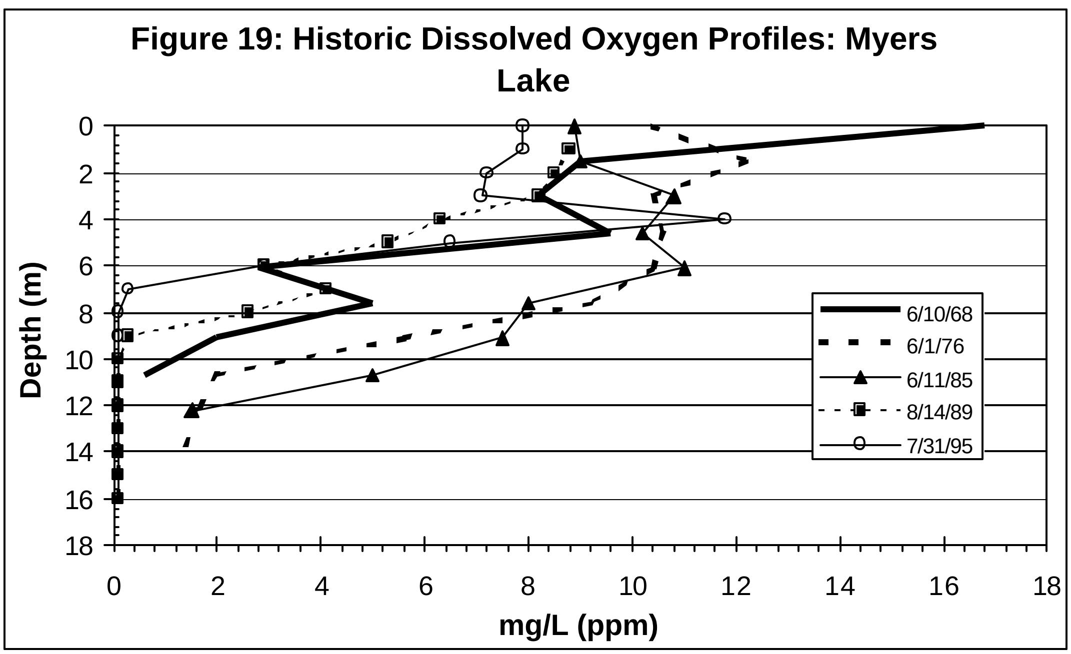

Figure 19. Compilation of five historic dissolved oxygen profiles from Myers Lake.

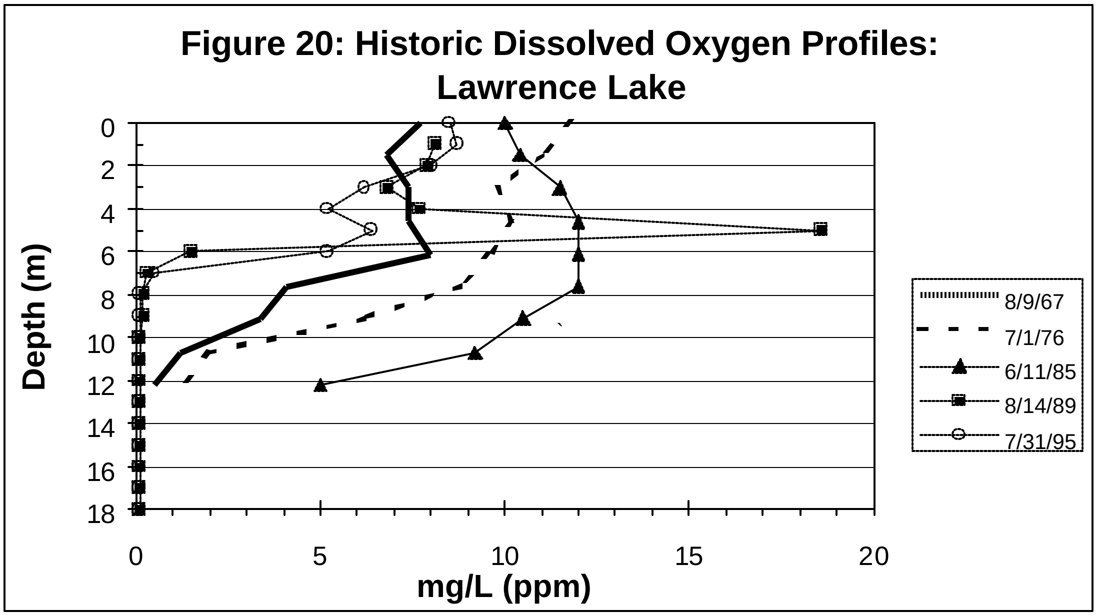

Figure 20. Compilation of five historic dissolved oxygen profiles from Lawrence Lake.

IN LAKE SAMPLING

Methods

The water sampling and analytical methods used for Lawrence and Myers Lakes were consistent with those used in IDEM's Indiana Clean Lakes Program and IDNR's Lake and River Enhancement Program. We collected water samples for various parameters on August 12, 1999 from the surface waters (***epilimnion***) and from the bottom waters (***hypolimnion***) of the lake. These parameters include pH, alkalinity, conductivity, total suspended solids, total phosphorus, soluble reactive phosphorus, nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, and organic nitrogen.

In addition to these parameters, several other measurements of lake health were recorded. Secchi disk, light transmission, and oxygen saturation are single measurements. Dissolved oxygen and temperature were measured at one-meter intervals from the surface to the bottom. Chlorophyll was determined only for an epilimnetic sample. A tow to collect plankton was made from the 1% light level to the water surface.

The comprehensive evaluation of lakes requires collecting data on a number of different, and sometimes hard-to-understand, water quality parameters. Some of the more important parameters that we analyze include:

<u>Phosphorus</u> Phosphorus is an essential plant nutrient, and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to lakes and there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in lakes. This means that the relative scarcity of phosphorus in lakes may limit the ultimate growth and production of algae and rooted aquatic plants. Therefore, lake management efforts often focus on reducing phosphorus inputs to lakes because: (a) it can

be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

Soluble reactive phosphorus (SRP) **–** SRP is dissolved phosphorus readily usable by algae. SRP is often in very low concentrations in lakes with dense algae populations where it is tied up in the algae themselves. SRP may be released from storage in sediments when dissolved oxygen is lacking.

Total phosphorus (TP) **–** TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.04 mg/L (or 40 μg/L) can cause algal blooms.

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the air we breathe is nitrogen gas. This nitrogen can diffuse into water where it can be "fixed", or converted, by blue-green algae for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to lakes. The three common forms of nitrogen are:

Nitrate (NO_3) **–** Nitrate is dissolved nitrogen that is converted to ammonia by algae. It is found in lakes when dissolved oxygen is present, usually the surface waters.

Ammonia (NH_4) **–** Ammonia is dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is found where dissolved oxygen is lacking, often in the hypolimniona of eutrophic lakes.

Organic Nitrogen (Org N) **–** Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In our analytical procedures, we analyze total Kjeldahl nitrogen (TKN). Organic nitrogen is TKN minus ammonia.

Dissolved Oxygen (D.O.) D.O. is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 parts per million (ppm) of D.O. Cold water fish such as trout and cisco generally require higher concentrations of D.O. than warm water fish such as bass or bluegill. D.O. affects a variety of chemical reactions in water. For example, the lack of D.O. near the bottom sediments may allow dissolved phosphorus (SRP) to be released from the sediments into the water. If less than 50% of a lake's water column has oxygen, greater hypolimnetic concentrations of SRP and ammonia are common as well. D.O. enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with D.O. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Secchi Disk Transparency. Secchi disk transparency is the depth to which the black & white Secchi disk can be seen in the water. Water clarity, as determined by a Secchi disk, is affected by two primary factors: algae and suspended particulate matter. Particulates (for example, soil or dead leaves) may be introduced into the water by either runoff from the land or from sediments already on the bottom of the lake. Many processes may introduce sediments from runoff; examples include erosion from construction sites, agricultural lands and riverbanks. Bottom sediments may be resuspended by bottom feeding fish such as carp, or in shallow lakes, by motorboats or strong winds.

Light Transmission. Similar to the Secchi disk transparency, this measurement uses a light meter (photocell) to determine the rate at which light transmission is diminished in the upper portion of the water column. Another important light transmission measurement is the 1% light level. The 1% light level is the water depth to which one percent of the surface light penetrates. This is considered the lower limit of algal growth.

Plankton. Plankton are important members of the aquatic food web. They include algae (microscopic plants) and zooplankton (tiny shrimp-like animals that eat algae). Plankton density is determined by filtering water through a net having a very fine mesh (63 micron openings = 63/1000 millimeter). The plankton net is towed up through the water column from the one percent light level to the surface. Of the many different algal species present in the water, the blue-green algae are of particular interest. Blue-green algae are those that most often form nuisance blooms; their dominance in lakes may indicate poor water conditions.

Chlorophyll *a*. The plant pigments of algae consist of the chlorophylls (green color) and carotenoids (yellow color). Chlorophyll *a* is by far the most dominant chlorophyll pigment and occurs in great abundance. Thus, chlorophyll *a* is often used as a direct estimate of algal biomass.

Results

Tables 14 and 15 and Figures 21 and 22 summarize the results of the in lake sampling on Myers and Lawrence Lake.

Table 14. Water Quality Characteristics of Myers Lake on 8/12/99

Parameter	Epilimnetic Sample (1m)	Hypolimnetic Sample (3m)	Indiana TSI Points (based on mean values)
PH	8.4	7.6	-
Alkalinity	136.0 mg/L	176 mg/L	-
Conductivity	393 µmhos	279 µmhos	-
Total Suspended Solids	2.68 mg/L	2.33 mg/L	-
Secchi Disk Transp.	1.4 meters	-	6
Light Transmission @ 3 ft	45 %	-	3
1% Light Level	17 feet	-	-
Total Phosphorus	0.028 mg/L	0.108 mg/L	3
Soluble Reactive Phos.	0.028 mg/L	0.105 Mg/L	3
Nitrate-Nitrogen	<0.022 mg/L	<0.022 mg/L	0
Ammonia-Nitrogen	<0.018 mg/L	0.574 mg/L	0
Total Kjeldahl Nitrogen	0.883 mg/L	1.225 mg/L	
Organic Nitrogen	0.865 mg/L	0.651 mg/L	2
Oxygen Saturation @ 5 ft.	82.1 %	-	0
% Water Column Oxic	29 %	-	3
Plankton Density	883 per L	-	0
Blue-Green Dominance	No	-	0
Chlorophyll *a*	3.00 µg/L	-	-

TSI Score 20

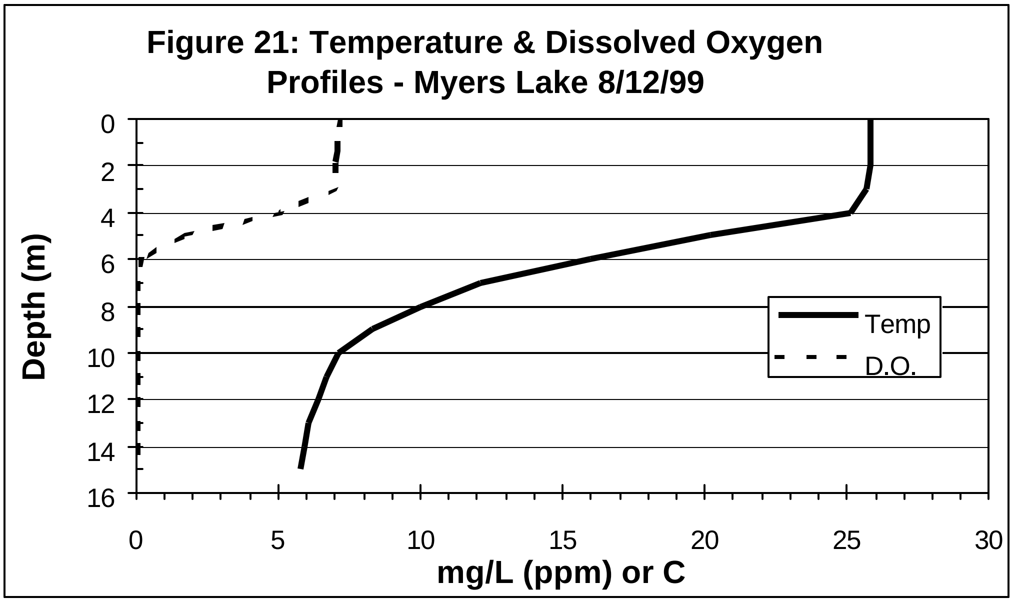

Figure 21: Temperature & Dissolved Oxygen Profiles – Myers Lake 8/12/99

Table 15. Water Quality Characteristics of Lawrence Lake on 8/12/99

Parameter	Epilimnetic Sample (1m)	Hypolimnetic Sample (3m)	Indiana TSI Points (based on mean values)
pH	8.6	7.3	-
Alkalinity	126 mg/L	184 mg/L	-
Conductivity	381 μmhos	294 μmhos	-
Total Suspended Solids	1.20 mg/L	6.01 mg/L	-
Secchi Disk Transp.	2.9 meters	-	0
Light Transmission @ 3 ft	35 %	-	3
1% Light Level	25 feet	-	-
Total Phosphorus	0.029 mg/L	0.248 mg/L	3
Soluble Reactive Phos.	0.026 mg/L	0.135 mg/L	3
Nitrate-Nitrogen	<0.022 mg/L	<0.022 mg/L	0
Ammonia-Nitrogen	<0.018 mg/L	1.349 mg/L	3
Total Kjeldahl Nitrogen	0.493 mg/L	2.106 mg/L	-
Organic Nitrogen	0.475 mg/L	0.757 mg/L	2
Oxygen Saturation @ 5 ft.	95.4 %	-	0
% Water Column Oxic	56 %	-	2
Plankton Density	884 per L	-	0
Blue-Green Dominance	No	-	0
Chlorophyll *a*	2.60 μg/L	-	-

TSI Score 16

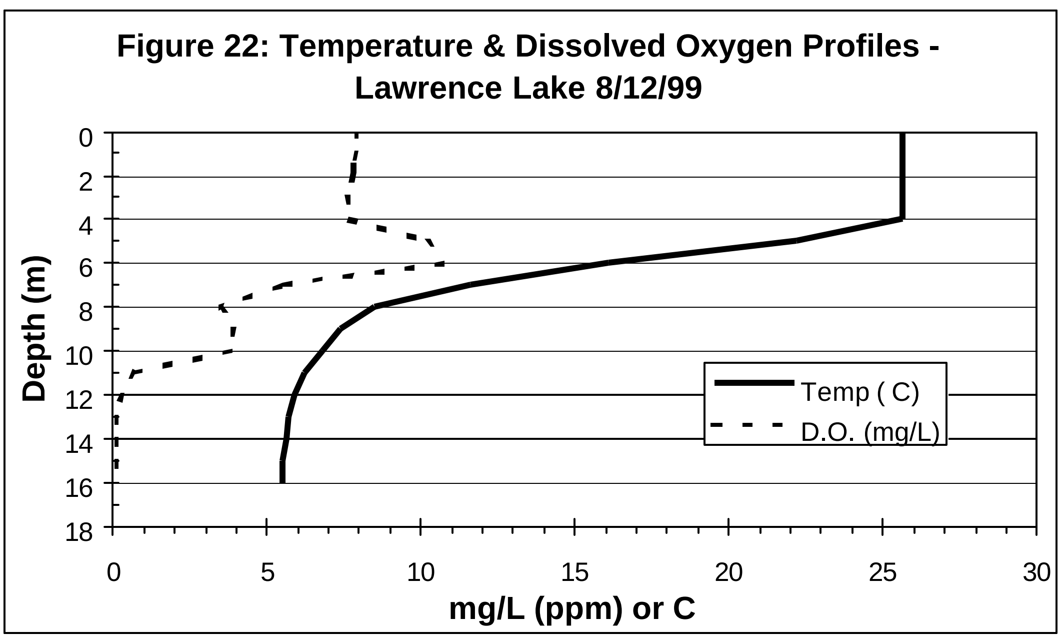

Figure 22: Temperature & Dissolved Oxygen Profiles – Lawrence Lake 8/12/99

Temperature and oxygen profiles

Temperature and oxygen profiles for Myers and Lawrence Lakes show that the lakes were stratified at the time of sampling (Figures 21 and 22). During thermal stratification, the bottom waters (***hypolimnion***) of the lake are isolated from the well-mixed surface waters (***epilimnion***) by temperature-induced density differences. The boundary between these two zones, where temperature changes most rapidly with depth is called the ***metalimnion***. At the time of our sampling, the epilimnion of Myers Lake was confined to the upper 13 feet (4 meters) of water. The sharp decline in temperature between 13 and about 32 feet (4 and 10 meters) defines the metalimnion or transition zone. The hypolimnion occupied water deeper than 32 feet (10 meters).

The epilimnion of Lawrence Lake occupies the upper 13 feet (4 meters) of water. The lake's metaliminion was defined by the sharp decline in temperature between 13 and about 26 feet (4 and 8 meters). Water deeper than 8 meters makes up the lake's hypolimnion.

Myers Lake's oxygen profile follows a pattern similar to its temperature profile. Oxygen is plentiful in the epilimnion where the circulating lake water gains oxygen from the atmosphere and from photosynthesizing algae. Below this point, oxygen concentrations decline rapidly as bacteria decompose algae while settling through the water column. Below 20 feet (6 meters), decomposition processes have consumed all the oxygen and the lake is anoxic. Referring back to the depth-volume curve in Figure 10, we can determine that only 57% of the lake's volume (the volume between the surface and 20 feet or 6 meters) has enough oxygen to support fish and other aquatic life that require oxygen.

Lawrence Lake has an interesting oxygen profile. The epilimnion is nearly saturated with oxygen but concentrations increase to 117% saturation at 16.5 feet (5 meters). This phenomenon is known as a metalimnetic oxygen maximum and is likely due to a high density of photosynthesizing algae positioned in the upper metalimnion where there is still adequate light and where they have access to more plentiful nutrients in the hypolimnion. Below this point, oxygen concentrations decline rapidly as bacteria decompose algae while settling through the water column. We usually see this type of oxygen profile in lakes that are clear enough to allow light to penetrate that deeply. Lower decomposition rates from 26 to 32 feet (8 to 10 meters) give the appearance of increasing oxygen concentrations but oxygen concentrations are simply returning to normal. Below 32 feet (10 meters), decomposition again increases and the remaining oxygen is consumed by 39 feet (12 meters). This suggests that approximately 75 % of the lake's volume has enough oxygen to support fish and other aquatic life that requires oxygen.

Nutrients

Phosphorus and nitrogen are the primary plant nutrients in lakes. Concentrations of these nutrients are relatively low in the surface waters of both lakes. Higher concentrations of phosphorus in the lakes' hypolimniona indicate that phosphorus is being liberated from the sediments due to the anoxic, chemically reducing conditions there. The concentration of soluble reactive phosphorus in the lakes' epilimniona is low because this dissolved form is rapidly taken up and used by algae and other plants.

Because ammonia is a by-product of the decomposition of organic matter, ammonia concentrations are also higher in the hypolimniona where decomposition rates are high and where ammonia is not oxidized.

Alkalinity

Alkalinity is a measure of the water's ability to resist change in pH, or acid content. It is also referred to as a lake's acid neutralizing capacity or buffering capacity. This buffering action is important because it ensures a relatively constant chemical and biological environment in lakes. Alkalinity is determined largely by the availability and chemistry of carbonate in water. Sources of carbonate to natural waters include limestone (calcium carbonate) and carbon dioxide. The high alkalinity concentrations found in both lakes indicate that both Myers and Lawrence Lakes are well-buffered systems.

pH and Conductivity

In both lakes, the measured pH levels are slightly higher in the epilimnion where the process of photosynthesis consumes carbon dioxide, a weak acid. The lack of photosynthesis in the hypolimnion, and the liberation of carbon dioxide by respiring bacteria keep pH levels lower in the hypolimnion. Conductivity values, a measure of dissolved ions, are within the normal range for Indiana lakes.

1% Light Level

The 1% light level, which limnologists use to determine the lower limit where photosynthesis can occur, extended to a depth of 17 feet (5.2 meters) in Myers Lake and 25 feet (7.6 meters) in Lawrence Lake. The depth to which light can penetrate is affected by particles (algae, sediments, etc.) suspended in the water. In Lawrence Lake, the rather deep 1% light depth results from the low total suspended solids and plankton concentrations. Particulate matter in the Myers Lake water column decreases the depth of light penetration.

Based on the depth-volume curves (Figures 10 and 12), we can determine the volume of each lake with sufficient light to support algae. In Myers Lake, the upper 51% of the water volume in the lake has sufficient light to support algae. In contrast, approximately 62% of the water volume in Lawrence Lake has sufficient light to support algae.

Discussion

The interpretation of a comprehensive set of water quality data can be quite complicated. Often, attention is directed at the important plant nutrients (phosphorus and nitrogen) and to water transparency (Secchi disk) since dense algal blooms and poor transparency greatly affect the health and use of lakes.

To more fully understand the water quality data, it is useful to compare data from the lake in question to standards, if they exist, to other lakes, or to criteria that most limnologists agree upon. Because there are no nutrient standards for Indiana lakes, we must compare the Myers and Lawrence Lakes results with data from other lakes and with other generally accepted criteria.

Comparison With Vollenweider's Data

Results of studies conducted by Richard Vollenweider in the 1970's are often used as guidelines for evaluating concentrations of water quality parameters. His results are given in Table 16 below. Vollenweider relates the concentrations of selected water quality parameters to a lake's *trophic state.* The trophic state of a lake refers to its overall level of nutrition or biological productivity. Trophic categories include: *oligotrophic, mesotrophic, eutrophic* and *hypereutrophic*. Lake conditions characteristic of these trophic states are:

Oligotrophic - lack of plant nutrients keep productivity low; lake contains oxygen at all depths; clear water, deeper lakes can support trout.

Mesotrophic - moderate plant productivity; hypolimnion may lack oxygen in summer; moderately clear water, warm water fisheries only - bass and perch may dominate.

Eutrophic - contains excess nutrients; blue-green algae dominate during summer; algae scums are probable at times; hypolimnion lacks oxygen in summer; poor transparency; rooted macrophyte problems may be evident.

Hypereutrophic - algal scums dominate in summer; few macrophytes; no oxygen in hypolimnion; fish kills possible in summer and under winter ice.

The units in Table 16 are either milligrams per liter (mg/L) or micrograms per liter (µg/L). One mg/L is equivalent to one part per million (PPM) while one microgram per liter is equivalent to one part per billion (PPB). The values presented below are mean values from epilimnetic and hypolimnetic samples. It should be noted that these are only guidelines, similar concentrations in a particular lake may not cause problems if something else is limiting the growth of algae or rooted plants.

Table 16. Mean Values of Some Water Quality Parameters and Their Relationship to Lake Production. (after Vollenweider, 1979)

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Total Phosphorus (mg/L or PPM)	0.008	0.027 *	0.084 #	>0.750
Total Nitrogen (mg/L or PPM)	0.661	0.753 * #	1.875	-
Chlorophyll *a* (µg/L or PPB)	1.7 * #	4.7	14.3	-

The values for Myers Lake are indicated by the asterisk (*) while the values for Lawrence Lake are indicated a numerical sign (#) in the table above. For Myers Lake, the total phosphorus and total nitrogen concentrations exceed the mean for mesotrophic lakes, while the chlorophyll *a* concentration exceeds the mean for oligotrophic lakes. These comparisons suggest that Myers Lake can be classified as a mesotrophic lake by Vollenweider's standards.

For Lawrence Lake, the total phosphorus concentration exceeds the mean concentration for eutrophic lakes, while the total nitrogen concentration exceeds the mean concentration for mesotrophic lakes. The chlorophyll *a* concentration exceeds the mean for oligotrophic lakes. Based on this data, Lawrence Lake does not readily fall in one of Vollenweider's categories.

Comparison With Other Indiana Lakes

The Myers and Lawrence Lakes results can also be compared to other Indiana lakes. Table 17 presents data from 355 Indiana lakes collected during July and August 1994-98 under the Indiana Clean Lakes Program. The set of data summarized in the table represent median values of epilimnetic and hypolimnetic samples for each of the 355 lakes. (The Myers and Lawrence Lakes values are also mean values of the epilimnetic and hypolimnetic samples.) Again, it should be noted that a wide variety of conditions, including geography, morphometry, time of year, and watershed characteristics, could influence the water quality of lakes. Thus, it is difficult to predict and even explain the reasons for the water quality of a given lake.

Table 17. Water Quality Characteristics of 355 Indiana Lakes Sampled From 1994 thru 1998 by the Indiana Clean Lakes Program.

	Secchi Disk (m)	NO_3 (mg/L)	NH_4 (mg/L)	TKN (mg/L)	Total Phos (mg/L)	SRP (mg/L)	Chl. *a* (μg/L)
Median	1.8	0.025	0.472	1.161	0.097	0.033	5.33
Maximum	9.2	9.303	11.248	13.794	4.894	0.782	230.9
Minimum	0.1	0.022	0.018	0.230	0.001	0.001	0
Myers	**1.4**	**0.022**	**0.296**	**1.105**	**0.068**	**0.067**	**3.00**
Lawrence	**2.9**	**0.022**	**0.684**	**1.300**	**0.139**	**0.081**	**2.60**

The Myers Lake results are less than the median values for Indiana lakes for all parameters except for Secchi disk (a negative parameter) and SRP. In contrast, the Lawrence Lake results for ammonia, total Kjeldahl nitrogen, total phosphorus, and soluble reactive phosphorus all exceed the median values for the Indiana lakes included in the table. Based on this, we can conclude that most Indiana lakes have worse water quality than Myers Lake and better water quality than Lawrence Lake.

Using a Trophic State Index

In addition to simple comparisons to other lakes, lake water quality data can be evaluated through the use of a trophic state index or TSI. Indiana and many other states use a trophic state index (TSI) to help evaluate water quality data. A TSI condenses water quality data into a single, numerical index. Different index (or eutrophy) points are assigned for various water quality concentrations. The index total, or TSI, is the sum of individual eutrophy points for a lake.

The Indiana TSI

The Indiana TSI ranges from 0 to 75 total points. The TSI totals are grouped into the following three lake quality classifications:

TSI Total	Water Quality Classification
0-25	highest quality (oligotrophic)
26-50	intermediate quality (mesotrophic)
51-75	lowest quality (eutrophic)

A rising TSI score for a particular lake from one year to the next indicates that water quality is worsening while a lower TSI score indicates improved conditions. However, natural factors such as climate variation can cause changes in TSI score that do not necessarily indicate a long-term change in lake condition. Parameters and values used to calculate the Indiana TSI are given in Table 18.

Table 18. The Indiana Trophic State Index

		Parameter and Range	Eutrophy Points
I.	Total Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
II.	Soluble Phosphorus (ppm)		
	A.	At least 0.03	1
	B.	0.04 to 0.05	2
	C.	0.06 to 0.19	3
	D.	0.2 to 0.99	4
	E.	1.0 or more	5
III.	Organic Nitrogen (ppm)		
	A.	At least 0.5	1
	B.	0.6 to 0.8	2
	C.	0.9 to 1.9	3
	D.	2.0 or more	4
IV.	Nitrate (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.8	2
	C.	0.9 to 1.9	3

	D.	2.0 or more	4
V.	Ammonia (ppm)		
	A.	At least 0.3	1
	B.	0.4 to 0.5	2
	C.	0.6 to 0.9	3
	D.	1.0 or more	4
VI.	Dissolved Oxygen: Percent Saturation at 5 feet from surface		
	A.	114% or less	0
	B.	115% 50 119%	1
	C.	120% to 129%	2
	D.	130% to 149%	3
	E.	150% or more	4
VII.	Dissolved Oxygen: Percent of measured water column with at least 0.1 ppm dissolved oxygen		
	A.	28% or less	4
	B.	29% to 49%	3
	C.	50% to 65%	2
	D.	66% to 75%	1
	E.	76% 100%	0
VIII.	Light Penetration (Secchi Disk)		
	A.	Five feet or under	6
IX.	Light Transmission (Photocell) : Percent of light transmission at a depth of 3 feet		
	A.	0 to 30%	4
	B.	31% to 50%	3
	C.	51% to 70%	2
	D.	71% and up	0
X.	Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface:		
	A.	less than 3,000 organisms/L	0
	B.	3,000 - 6,000 organisms/L	1
	C.	6,001 - 16,000 organisms/L	2
	D.	16,001 - 26,000 organisms/L	3
	E.	26,001 - 36,000 organisms/L	4
	F.	36,001 - 60,000 organisms/L	5
	G.	60,001 - 95,000 organisms/L	10
	H.	95,001 - 150,000 organisms/L	15

I.	150,001 - 5000,000 organisms/L	20
J.	greater than 500,000 organisms/L	25
K.	Blue-Green Dominance: additional points	10

The Indiana Trophic State Index value calculated for Myers Lake is 20 (see Table 14). Lawrence Lake scores similarly well with an Indiana TSI value of 16 (see Table 15). These scores place Myers and Lawrence Lakes within the "highest quality" range of the index. This conclusion is also inconsistent with the physical appearance of the lakes (abundant rooted aquatic plants) and with the measured values for phosphorus and Secchi disk transparency. There are several possible reasons for this:

1) In lakes with high non-algal turbidity (suspended inorganic material), light penetration (and therefore photosynthesis) is reduced. This would yield fewer algae in the samples. Algae can account for a total of 35 trophic points in the Indiana TSI.
2) The Indiana TSI does not account for rooted aquatic plants.
3) The dense growths of rooted aquatic plants ringing the lakes in the shallow waters intercept runoff water, trapping suspended solids. These rooted plants also compete with the algae for available phosphorus. Note that epilimnetic phosphorus concentrations are very low – there is little phosphorus available to the algae.

The Indiana TSI has not been statistically validated and it tends to rely too heavily on algae and does not weight poor transparency or nutrients high enough in the total score. For these reasons, the Carlson TSI (Carlson, 1977) may be more appropriate to use in evaluating Indiana lake data.

The Carlson TSI

The most widely used and accepted TSI is one developed by Bob Carlson called the Carlson TSI. Carlson analyzed summertime total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among the three parameters. He developed mathematical equations for these relationships and used these for the basis for the Carlson TSI. Using this index, a TSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll *a* or total phosphorus. Data for one parameter can also be used to predict a value for another. The TSI values range from 0 to 100. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass.

As a further aid in interpreting TSI results, Carlson's scale is divided into four lake productivity categories: oligotrophic (least productive), mesotrophic (moderately productive); eutrophic (very productive) and hypereutrophic (extremely productive).

Using Carlson's index, a lake with a summertime Secchi disk depth of 1 meter would have a TSI of 60 points (located in line with the 1 meter). This lake would fall in the mesotrophic category. Because the index was constructed using relationships among transparency, chlorophyll, and total phosphorus, a lake having a Secchi disk depth of 1 meter would also be expected to have 20 μg/L chlorophyll and 43 μg/L total phosphorus.

Not all lakes have the same relationship between transparency, chlorophyll and total phosphorus as Carlson's lakes do. Other factors such as high suspended sediments or heavy predation of algae by zooplankton may keep chlorophyll concentrations lower than might be otherwise expected from the total phosphorus concentrations. High suspended sediments would also make transparency worse than otherwise predicted by Carlson's index.

It is also useful to compare the actual trophic state points for a particular lake from one year to the next to detect any trends in changing water quality. While climate and other natural events will cause some variation in water quality over time (possibly 5-10 trophic points), larger point changes may indicate important changes in lake quality.

Figure 23: Carlson's Trophic State Index

```
                 Oligotrophic     Mesotrophic    Eutrophic   Hypereutrophic

                  20    25    30    35    40    45    50     55    60    65     70    75
80
Trophic State
    Index       +------------------------------------------------------------+

                  15    10  8 7  6   5    4     3     2   1.5     1          0.5     0.3
Transparency
(Meters)        +---------------------------#--------*------------------------

                     0.5       1      2      3  4  5   7   10  15  20   30  40  60 80 100
150
Chlorophyll-a
(μg/L or PPB)   +--------------------#-*-------------------------------------+

 Total            3      5      7     10     15    20  25 30   40  50  60  80  100    150
 Phosphorus
(μg/L or PPB)   +----------------------------------------------*-------#-----+
```

* denotes mean values for Myers Lake
# denotes mean values for Lawrence Lake

Comparison of Myers Lake data with Carlson's criteria place the Secchi disk value within the eutrophic category, the chlorophyll-a data within the mesotrophic category, and total phosphorus data within the hypereutrophic category (see asterisks in figure above). Internal loading of phosphorus from the sediments causes the hypolimnetic TP concentration to be so high. Fortunately, most of this phosphorus is confined to the hypolimnion during the growing season where it cannot support additional algal growth. Overall, analysis using Carlson's TSI is similar to the results comparing our data with Vollenweider's data and is, we believe, a better measure of the true trophic status of Myers Lake.

Analysis of Lawrence Lake transparency and chlorophyll *a* data according to Carlson's TSI shows that these parameters register in the mesotrophic categories (see numerical symbols in figure above). The phosphorus data fall within the hypereutrophic range, primarily due to the high internal loading of phosphorus from the sediments. This is similar to the results comparing our data with Vollenweider's data and is, we believe, a better measure of the true trophic status of Lawrence Lake.

<u>Plankton</u>

The plankton population at the time of our sampling was very sparse in both lakes. Diatoms and yellow-brown algae dominated the algae community. Blue-green algae, the algal group most often associated with nuisance blooms, accounted for only 25% of the total number of cells in the Myers sample and only 12% of the total in the Lawrence sample. Appendix 7 provides a complete list of algae and plankton found in Myers and Lawrence Lakes.

Algae like most green plants depend on light and several important nutrients for their growth. If any of the essentials needed for growth are in limited supply, algal growth will not achieve its maximum rate. The material in least supply is known as growth limiting. The ratio of nitrogen and phosphorus in plant tissue is 7 parts nitrogen to 1 part phosphorus. In Myers Lake, the ratio of total nitrogen to total phosphorus in the surface water where growth can occur is 15.8 : 1. Lawrence Lake has a similar ratio, 17.8 : 1. Because there is much more nitrogen available relative to phosphorus, phosphorus is the limiting nutrient in both lakes. This means that if more phosphorus is added to the water, more algal growth will result. Therefore, to prevent additional algal growth or to reduce existing algal populations, phosphorus additions to the lake must be controlled. This includes phosphorus from sediment as well as external inputs from lawn fertilizers, yard waste, and agricultural runoff.

WATER BUDGET

<u>Lawrence Lake</u>

Because there are no streams, rivers or other channels discharging into Lawrence Lake, inputs of water to the lake are limited to:

- direct precipitation to the lake
- sheet runoff from land immediately adjacent to the lake
- groundwater

Water leaves the lake from:

- discharge from the outlet channel to Myers Lake
- evaporation
- groundwater

There are no gauges on the lake to measure water inputs or outputs so we must estimate this from other records. Direct precipitation to the lake can be calculated from mean annual precipitation and the lake's surface area. Runoff from the lake's watershed can be estimated by applying runoff coefficients. A runoff coefficient refers to the percentage of precipitation that occurs as surface runoff, as opposed to that which soaks into the ground. Runoff coefficients may be estimated by comparing discharge from a nearby gauged watershed to the total amount of precipitation falling on that watershed. The nearest gauged watershed to Lawrence Lake is a U.S.G.S. gauging station on the Yellow River at Plymouth, Indiana (Stewart et al., 1998). When the 20-year daily mean discharge for this watershed is annualized and compared to mean annual precipitation, a runoff coefficient of 0.366 is derived. This means that 36.6% of the rainfall falling on this watershed runs off on the land surface. No groundwater records exist for the lake so we must assume that groundwater inputs equal outputs. Annual water budget input estimates for Lawrence Lake are summarized in Table 19.

Table 19. Annual Water Budget Estimates for Lawrence Lake.

Category	Operation	Result
Direct Precipitation	Mean annual precip x lake surface area	(36.78 in/yr)(1 ft/12 in)(69 acres)(43,560 ft^2/acre) = **9.212 x 10^6 ft^3/yr**
Surface Runoff	Mean annual precipitation x watershed area x runoff coefficient	(36.78 in/yr)(1ft/12 in)(278 ac)(43,560 ft^2/acre) (0.366) = **1.358 x 10^7 ft^3/yr**
TOTAL		**2.279 x 10^7 ft^3/yr (6.5 x 10^5 m^3/yr)**

Based on this input water volume (22,790,000 ft^3/yr or 6.5 x 10^5 m^3/yr) and the lake's volume (55,034,374 ft^3 or 1,558,574 m^3), the *hydraulic residence time* of Lawrence Lake is 2.4 years. This means that it takes approximately 2.4 years for the lake's entire volume to be replaced by direct precipitation and surface runoff. This value is so large due to the very small size of Lawrence Lake's watershed. The hydraulic residence of many natural *drainage lakes* (those with surface inlets and outlets) in Indiana is about one year.

Myers Lake

Inputs of water to Myers Lake are:

- discharge from Lawrence Lake
- direct precipitation to the lake
- sheet runoff from land immediately adjacent to the lake
- groundwater

Water leaves the lake from:

- discharge from the outlet channel
- evaporation

- groundwater

As on Lawrence Lake, there are no gauges on Myers to measure water inputs or outputs so we must estimate this from other records. We assumed that discharge from Lawrence Lake was equal to the inputs to Lawrence Lake less evaporative losses. Evaporation was estimated from pan evaporation data from the nearest station (Valparaiso Waterworks). Because pan evaporation exceeds actual lake evaporation by about 40%, we multiplied the total pan evaporation by a coefficient of 0.6. Direct precipitation to the lake can be calculated from mean annual precipitation and the lake's surface area. Runoff coefficients were calculated the same way they were for Lawrence Lake, and we assumed that groundwater inputs equal outputs. Annual water budget input estimates for Myers Lake are summarized in Table 20.

Table 20. Annual Water Budget Estimates for Myers Lake.

Category	Operation	Result
Discharge from Lawrence Lake	Inputs – evaporative losses	(2.279 x 10^7 ft^3/yr)(16.83 in/yr)(1ft/12in)(69 ac)(43,560 ft^2/acre) = **1.857 x 10^7 ft^3/yr**
Direct Precipitation	Mean annual precip x lake surface area	(36.78 in/yr)(1 ft/12 in)(96 acres)(43,560 ft^2/acre) = **1.282 x 10^7 ft^3/yr**
Surface Runoff	Mean annual precipitation x watershed area x runoff coefficient	(36.78 in/yr)(1ft/12 in)(405 ac)(43,560 ft^2/acre) (0.366) = **1.979 x 10^7 ft^3/yr**
TOTAL		**5.118 x 10^7 ft^3/yr (1.4 x 10^6 m^3/yr)**

Based on this input water volume (51,180,000 ft^3/yr or 1.4 x 10^6 m^3/yr) and the volume of Myers Lake (68,035,509 ft^3 or 1,926,766 m^3), the *hydraulic residence time* is 1.33 years. This means that it takes approximately 1.33 years for the lake's entire volume to be replaced by direct precipitation and surface runoff. As with Lawrence Lake, this value is large due to the rather small size of Myers Lake's watershed. As previously stated, the hydraulic residence of many natural *drainage lakes* (those with surface inlets and outlets) in Indiana is about one year.

To illustrate how watershed size can influence hydraulic residence time, one can compare Myers and Lawrence Lakes to Lake Tippecanoe in Koscuisko County. Tippecanoe's watershed, which is approximately 115 square miles (294.4 square km), is much larger than either the Myers or Lawrence watersheds and the ratio of Tippecanoe's watershed area to lake size of approximately 93:1 greatly exceeds the watershed area to lake area ratios for Myers and Lawrence (approximately 5:1). Consequently, one would expect the hydraulic residence time of Tippecanoe to be shorter than that observed for Myers and Lawrence Lakes. Lake Tippecanoe has a hydraulic residence time of approximately 4.5 months.

PHOSPHORUS BUDGET

Because phosphorus is the primary nutrient regulating the growth of algae in lakes, it is helpful to develop a phosphorus budget for lakes. The limited scope of this LARE study did not allow for a determination of phosphorus inputs and outputs outright. Therefore, a standard phosphorus model was used to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies and calculated phosphorus export coefficients for each land use in the watershed. Using conservative estimates of these phosphorus export coefficient values, which are expressed as kilograms of phosphorus lost per hectare of land per year, and multiplying them by the amounts of land in each of the land use categories, an estimate of annual phosphorus export (as kg/year) for each land use per watershed was calculated (Tables 21 and 22).

Table 21. Estimated Watershed Phosphorus Export to Lawrence Lake.

LAND USE	P-export (kg/ha-yr)	Land Area (ha)	P-export (kg)
Agriculture	0.9	74.46	67.01
Pasture	0.2	0	0
Forest	0.1	0	0
Residential	0.5	38.04	19.02
TOTAL			**86.03**

Table 22. Estimated Watershed Phosphorus Export to Myers Lake.

LAND USE	P-export (kg/ha-yr)	Land Area (ha)	P-export (kg)
Agriculture	0.9	80.94	72.851
Pasture	0.2	12.14	2.43
Forest	0.1	46.14	4.61
Residential	0.5	24.69	12.35
TOTAL			**92.23**

Phosphorus Loading by Source

In addition to loading from the land uses in the watershed, phosphorus loading due to precipitation and septic systems was also calculated.

Lawrence Lake

For Lawrence Lake, direct phosphorus input via precipitation was estimated by multiplying mean annual precipitation in Marshall County (0.934 m/yr) times the surface area of Lawrence Lake (69 acres or

2.79×10^5 m^2) times a typical phosphorus concentration in Indiana precipitation (0.03 mg/L). The phosphorus load due to septic systems was estimated by multiplying the number of homes on the lake (51 permanent; 10 seasonal) times an estimated 3 people per home, times an occupancy rate of either 365 or 90 days per year per home, times a phosphorus export coefficient of 0.6 kg per capita-year, times a soil retention coefficient of 0.75 (Reckhow and Simpson, 1980). Under ideal circumstances, all of the phosphorus in septic systems is trapped in the soil resulting in none reaching the lake. For purposes of this model, it was assumed that 25% of the phosphorus entering septic systems reaches the lake and 75% is trapped in the soil. The results are shown in Table 23 together with the phosphorus loading estimate from the watershed. Combined these sources yielded an estimated total of 117.9 kg of external phosphorus to the lake per year.

Table 23. Estimated External Phosphorus Loading by Source: Lawrence Lake

SOURCE	PHOSPHORUS LOAD	PERCENTAGE
Watershed Phosphorus Exported	86.0 kg/yr	73%
Precipitation Phosphorus	7.8 kg/yr	7%
Septic Systems	24.1 kg/yr	20%
TOTAL PHOSPHORUS LOAD	**117.9 kg/yr**	**100%**

Myers Lake

Similar calculations were performed for Myers Lake. An estimate of direct phosphorus input via precipitation was obtained by multiplying mean annual precipitation in Marshall County by the surface area of Myers Lake (96 acres or 3.89×10^5 m^2) by a typical phosphorus concentration in Indiana precipitation (0.03 mg/L). The phosphorus load due to septic systems was estimated by multiplying the number of homes on the lake (63 permanent; 12 seasonal) times an estimated 3 people per home, times an occupancy rate of either 365 or 90 days per year per home, times a phosphorus export coefficient of 0.6 kg per capita-year, times a soil retention coefficient (Reckhow and Simpson, 1980).

An estimate of phosphorus loading in the discharge from Lawrence Lake was calculated by multiplying the annual discharge by the epilimnetic phosphorus concentration we measured in Lawrence Lake in August (0.029 mg/l). We used this value rather than the volume-weighted value since discharge from the lake occurs from the epilimnion. Even during unstratified periods, phosphorus sedimentation would keep the epilimnetic phosphorus concentration below the volume-weighted concentration. Our estimate likely underestimates the phosphorus load from Lawrence Lake but it is the most reasonable estimate possible. The results, shown in Table 24, yielded an estimated 148.1 kg of external phosphorus loading to Myers Lake per year.

Table 24. Estimated External Phosphorus Loading by Source: Myers Lake

SOURCE	PHOSPHORUS LOAD	PERCENTAGE
Loading from Lawrence Lake	15.3 kg/yr	10.3%
Watershed Phosphorus Exported	92.2 kg/yr	62.3%
Precipitation Phosphorus	10.9 kg/yr	7.4%
Septic Systems	29.7 kg/yr	20%
TOTAL PHOSPHORUS LOAD	**148.1 kg/yr**	**100%**

Vollenweider model

The above calculations show the external loading of phosphorus to Myers and Lawrence Lakes. Internal loading also contributes to a lake's observed phosphorus concentration. A phosphorus-loading model such as the widely used Vollenweider (1975) model provides a means for examining the relationships among the primary parameters that affect a lake's phosphorus concentration. Vollenweider's empirical model says that the concentration of phosphorus ([P]) in a lake is proportional to the areal phosphorus loading (L, in g/m^2 lake area – year, considers both internal and external loading), and inversely proportional to the product of mean depth ($\bar{z}$) and hydraulic flushing rate (p) plus a constant (10):

$$[P] = \frac{L}{10 + \bar{z}r}$$

Lawrence Lake

During the August 12, 1999 sampling of Lawrence Lake, the epilimnetic phosphorus concentration was 0.029 mg/L and the hypolimnetic phosphorus concentration was 0.248 mg/L. Considering the respective volumes of the epilimnion and hypolimnion from the depth-volume curve (Figure 12), a volume-weighted mean phosphorus concentration of 0.129 mg/L was calculated for the lake. For this calculation, the middle metalimnion (6 meter depth) was used as the division between the epilimnion and hypolimnion.

Now it is useful to ask the question, "How much phosphorus loading from all sources is required to yield a mean phosphorus concentration of 0.129 mg/L in Lawrence Lake?" Plugging this mean concentration along with the mean depth and flushing rate into Vollenweider's phosphorus loading model and solving for L results in an areal phosphorus loading rate (mass of phosphorus per unit area of lake) of 1.61 g/m^2-yr. This means that in order to get a mean phosphorus concentration of 0.129 mg/L in the lake, a total of 1.61 grams of phosphorus must be delivered to each square meter of lake surface area per year.

Total phosphorus loading (L_T) is composed of external phosphorus loading (L_E) and internal phosphorus loading (L_I). Since L_T = 1.61 g/m^2-yr and L_E = 0.42 g/m^2-yr (calculated from the watershed loading in Table 23), internal phosphorus loading (L_I) equals 1.19 g/m^2-yr. Thus, internal loading accounts for nearly 74% of total phosphorus loading to Lawrence Lake.

Myers Lake

Similar calculations made with data from Myers Lake yielded a volume-weighted mean phosphorus concentration for the lake of 0.062 mg/L and an areal phosphorus loading rate (mass of phosphorus per unit area of lake) of 1.01 g/m^2-yr. This means that in order to get a mean phosphorus concentration of 0.062 mg/L in the lake, a total of 1.01 grams of phosphorus must be delivered to each square meter of lake surface area per year.

Again, the total phosphorus loading (L_T) is composed of external phosphorus loading (L_E) and internal phosphorus loading (L_I). Since L_T = 1.01 g/m^2-yr and L_E = 0.38 g/m^2-yr (calculated from the watershed loading in Table X), internal phosphorus loading (L_I) equals 0.629 g/m^2-yr. Thus, internal loading accounts for approximately 62% of total phosphorus loading to Myers Lake.

Internal Phosphorus Sources

Where does this internal phosphorus come from? It is phosphorus (from dead plants, from fertilizers, etc.) that is stored in the sediments. This phosphorus can dissolve and re-enter the water when oxygen above the sediments is lacking. The resulting internal phosphorus loading can be a significant source of phosphorus in lakes and may promote additional plant growth (Figure 23).

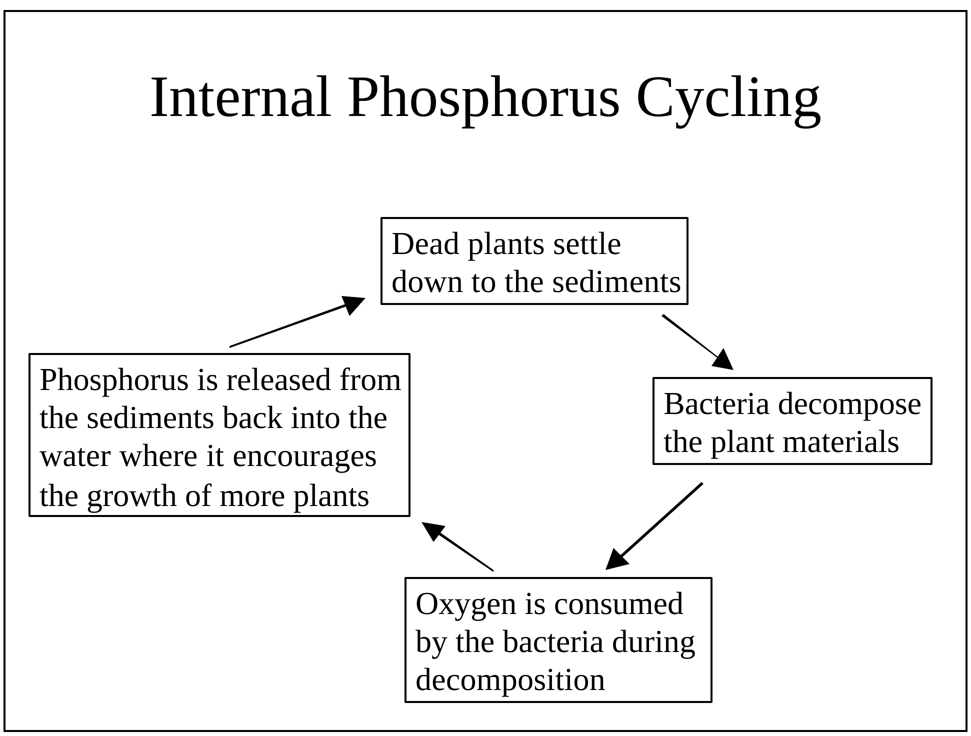

Figure 24. Anoxia at the sediments can cause chemically reducing conditions that can cause internal phosphorus release.

Areal Loading Rate

The significance of this areal loading rate is better illustrated in Figures 24 and 25 in which areal phosphorus loading is plotted against the product of mean depth and flushing rate. Overlain on this graph is a curve, based on Vollenweider's model, which represent an acceptable loading rate that yields a phosphorus concentration in lake water of 30 μg/L (0.03 mg/L). (Recall that total phosphorus concentrations above 0.04 mg/L may promote algae blooms.) Both Lawrence and Myers Lakes' loading rates fall within the excessive loading portion of the graphs.

This figure can also be used to evaluate management needs. For example, at Lawrence Lake areal phosphorus loading would have to be reduced to 0.38 g/m^2-yr to result in a mean lake water concentration of 30 μg/L. This represents a reduction in phosphorus mass loading to the lake of 345 kg/yr, a 77% reduction in total annual phosphorus loading.

Similar calculations for Myers Lake show the areal phosphorus loading would have to be reduced to 0.49 g/m^2-yr to result in a mean lake water concentration of 30 μg/L. This represents a reduction in phosphorus mass loading to the lake of 201 kg/yr or a 51% reduction in total annual phosphorus loading. Since this represents more phosphorus loading than enters the lake from all watershed sources (148 kg/yr), substantial improvement in phosphorus loading will require the reduction of internal phosphorus loading.

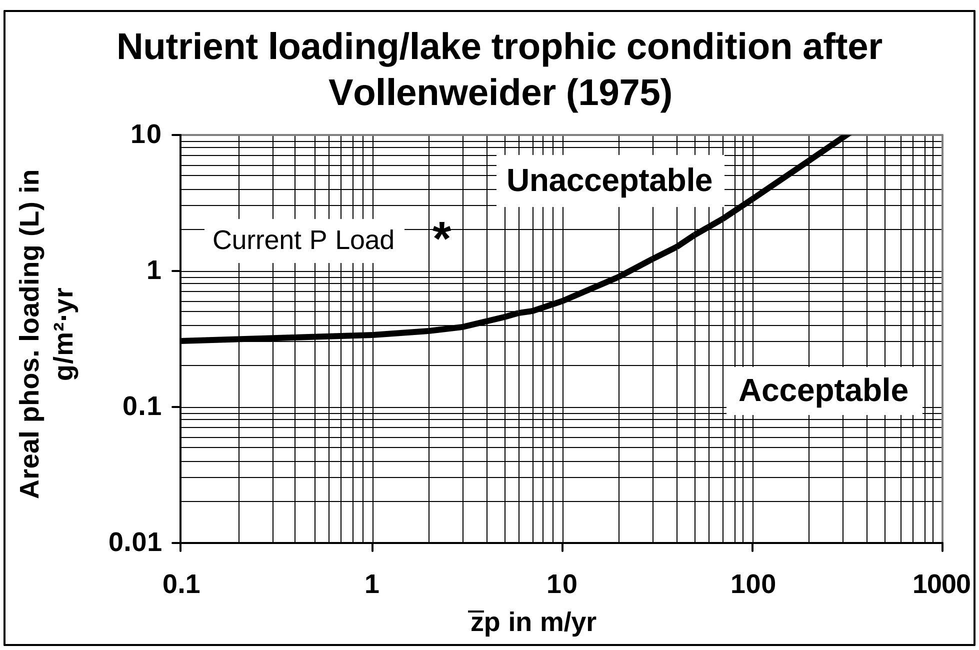

Figure 25. Current phosphorus loading rate for Lawrence Lake compared to a target loading rate that would result in an acceptable phosphorus concentration of 0.03 mg/L.

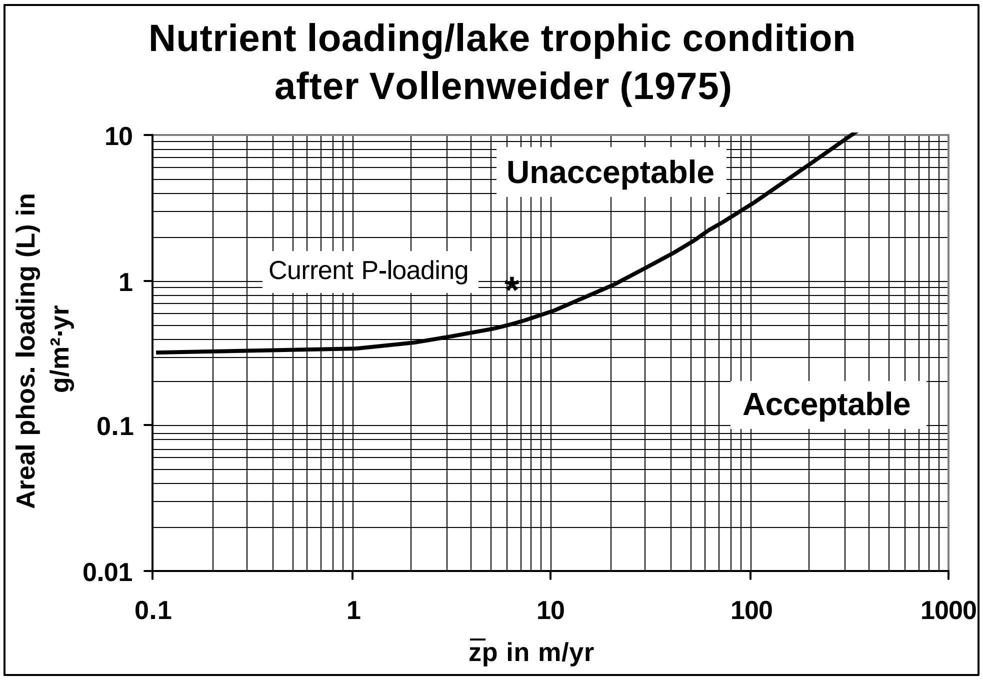

Figure 26. Current phosphorus loading rate for Myers Lake compared to a target loading rate that would result in an acceptable phosphorus concentration of 0.03 mg/L.

IN LAKE SUMMARY AND CONCLUSIONS

Lawrence Lake is a relatively clear lake with good water quality when compared to other Indiana lakes. However, symptoms of eutrophication are present and appear to be increasing. These symptoms include: declining dissolved oxygen concentrations in the hypolimnion, increased phosphorus and ammonia in the hypolimnion, and an extensive rooted plant community.

These same symptoms are apparent in Myers Lake as well. Myers Lake can best be described as a mesotrophic lake with the potential for much greater biological production due to the magnitude of internal phosphorus loading.

In both lakes, there is a significant amount of undecomposed organic material on the bottom sediments. Historical dissolved oxygen profiles suggest that this accumulation is getting worse with time. This material exerts a biochemical oxygen demand (BOD) in the deeper waters. As decomposer organisms (bacteria and microbes) feed on this organic material, they consume the available oxygen. Because of this, dissolved oxygen is virtually absent from the bottom half of the lake (water > 36 feet or 11 meters deep) in Lawrence Lake and the bottom 2/3 of the lake (water > 20 feet or 6 meters) in Myers Lake. This reduces available habitat for fish and other aquatic organisms. A further consequence of low oxygen levels is the creation of chemically reducing conditions. With reducing conditions inorganic phosphorus, otherwise tied up with iron and other cations in the sediments, is released back into the water. There is evidence of this internal phosphorus release in the higher hypolimnetic soluble phosphorus concentration compared with the epilimnetic concentration (0.135 mg/L compared to 0.026 mg/L in Lawrence and 0.105mg/L compared to 0.028 mg/L in Myers). Finally, the major product of bacterial decomposition is ammonia and ammonia concentrations are thus elevated in the hypolimniona of both lakes.

Fortunately, most of this internal loading of phosphorus occurs in the summer when the lakes are stratified and the released phosphorus is confined to the hypolimnion where it does not contribute to additional algal growth. This phosphorus mixes with the surface waters during fall overturn. By then (late September) algal growth is limited by shorter day length and cooler temperatures. Over time phosphorus concentrations will continue to increase throughout the lake and the growth of additional algae and rooted plants will occur if the internal releases of phosphorus are not controlled.

All of these data confirm the diagnosis of excessive organic matter inputs to the bottom sediments. External sources of organic material additions to lakes include: lawn wastes, leaves, and runoff water high in dissolved or suspended organic matter. Internal sources of organic material – dead algae and rooted aquatic plants – also contribute to BOD on the sediments. Given the low density of algae in the water at the time of our sampling, we suspect that the major source of this organic material is dead rooted aquatic plants. The extensive shallow areas (< 10-12 feet or 3-3.5 meters in depth) within the lakes provide ideal growing conditions for rooted plants. Each fall, when these plants die back, they settle onto the bottom sediments where the decomposing organisms feed on them throughout the summer. It is likely that there is more organic matter produced annually than can be consumed by the decomposers, so organic matter builds up in the sediments.

IN LAKE MANAGEMENT RECOMMENDATIONS

The problems identified in the analysis of Lawrence and Myers Lakes that require management include:

1. Oxygen depletion in deeper waters (hypolimnion).
2. Ammonia production in hypolimnion.
3. Phosphorus release from the sediments.

In addition to these, management plans should also address reduced water transparency in Myers Lake. There are several in-lake management alternatives available to address these problems.

<u>Aquatic Plant Management</u>

A comprehensive aquatic plant management program should be developed for both lakes. Such a program can address the first three of the problems identified above. As stated in the Plant Section of this document, all lakes need a diverse aquatic plant population to provide such benefits as fish and aquatic insect habitat, sediment stabilization, wave dampening, oxygen generation, etc. However, when aquatic plants become too dense or lack diversity, they may become a problem. This is what has happened in both Lawrence and Myers Lakes.

The major problems with the aquatic plant communities that can be addressed in a management program are:

1. Annual aquatic plant die-off contributes excessive organic material to the lake sediments that results in oxygen depletion, ammonia generation, and phosphorus release.
2. Plants are too dense for optimal fish production.
3. Dense plant beds interfere with human use of shallow areas of the lake.

It is important to understand that aquatic plant management does not mean aquatic plant eradication. Selective removal only is recommended. Management activities should target areas dominated by non-native plants, such as Eurasian water milfoil and curly leaf pondweed. In other areas, selective removal of rows through dense aquatic plant beds can create ‘cruising lanes’ for fish. These lanes allow predators (for example, largemouth bass) to get access to small, slow-growing prey species (bluegill, redear, etc.). This can increase the growth rates and size of predators and prey alike.

Extensive aquatic plant control is not recommended because as stated earlier, the rooted plants compete with the algae for available nutrients. When extensive aquatic plant management eliminates this competition, lakes often suffer extensive algal blooms. An aquatic plant management plan strives for a balance between rooted aquatic plants and the algae. By reducing the annual loading of plant biomass to the lake bottom, problems with oxygen depletion, ammonia generation, and phosphorus release can be reduced.

Several management techniques are described in the Plant Section of this document. Chemical control is currently used to manage the plant populations on both Lawrence and Myers. Harvesting and lake drawdown techniques may be better suited to the lake, however, as these practices remove plant material from the lake. (As noted earlier, however, drawdown is likely not practical on these lakes, so harvesting should be the focus.) Removal of plant material through harvesting prevents dead plants from contributing to the BOD problems cited previously. Chemical treatment, while effective in many cases, leaves the treated plant material in the lake where it adds BOD to the sediments.

Any harvesting plan should be tailored to target the Eurasian water milfoil and curly leaf pondweed. As noted in the Plant Section, these plants are aggressive, non-native plants that offer little value in terms of habitat compared to some of the native pondweeds. These species are capable of taking over a lake as evidenced on Myers Lake. While there are some concerns with regard to harvesting Eurasian water milfoil (Eurasion water milfoil can reproduce vegetatively from cut pieces), the benefits to Myers and Lawrence Lakes of removing much of the plant material and thereby reducing BOD may outweigh these concerns. Special techniques such as harvesting the plants at their roots and harvesting more than once a season has resulted in more successful control of Eurasian water milfoil (Cooke et al., 1993). Any harvesting program implemented on Myers and Lawrence Lakes should take these factors into consideration.

Phosphorus Precipitation and Inactivation

In addition to developing an aquatic macrophyte management plan, lake residents should consider controlling internal phosphorus release through a phosphorus precipitation and inactivation treatment. Phosphorus precipitation and inactivation is designed to remove phosphorus from the water column and to prevent release of phosphorus from sediments. This nutrient control strategy is aimed at minimizing planktonic algal growth. The treatment involves adding aluminum salts to the lake. These salts form a floc or an agglomeration of small particles. This floc (e.g. $Al(OH)_3$) acts in two ways: (a) it absorbs phosphorus from the water column as it settles, and (b) it seals the bottom sediments if a thick enough layer has been deposited. Phosphorus can also precipitate out as an aluminum salt (e.g. $AlPO_4$).

Most phosphorus precipitation treatments have employed liquid aluminum sulfate (alum) or sodium aluminate. The dosages are determined by a standard jar test, keeping in mind that aluminum solubility is lowest in the pH range 6.0 to 8.0. Cooke and Kennedy (1981) offer a detailed dose determination method. Aluminum toxicity does not appear to be a problem at treatment concentrations in well-buffered lakes as long as the pH remains above 6.0. Chemicals added for phosphorus control are applied either to the lake surface or to the hypolimnion, depending upon whether water column or sediment phosphorus control is most necessary.

The application procedure of aluminum salts to lake water has changed little since the first treatment in Horseshoe Lake, Wisconsin (Peterson et al. 1973). At Horseshoe Lake, alum slurry was pumped from a barge through a manifold pipe that trailed behind the vessel just below, and perpendicular to, the water surface. Today, new LORAN-guided high speed barges applying 4060 ft^3 (115 m^3) of liquid alum per day are the most advanced application vessels available (Cooke et al., 1993).

The season of application is critical for phosphorus removal, since different forms of phosphorus predominate in the water column on a seasonal basis. Phosphorus removal is most effective in early spring or late fall when most phosphorus is in an inorganic form that can be removed almost entirely by the floc.

Phosphorus inactivation has been effective for as long as twelve years. In shallow, wind-swept lakes or in such parts of lakes, however, the floc may break up and lose its capabilities as a sealant. Application costs using the new, a high-speed barge is about $260/acre or $640/hectare (Cooke et al., 1993).

The alum treatment area would only need to be over water deeper than about 25 feet (7.6 meters) on Lawrence Lake and water deeper than about 20 feet (6 meters) on Myers Lake. This would treat the sediments overlaid with hypolimnetic water that are most likely to release phosphorus. Using this criterion, the treatment area would be approximately 28 acres (11.3 hectares) on Lawrence and approximately 43 acres (17 hectares) on Myers.

Controlling Sediment Disturbances

The extensive shallow water areas within Myers Lake facilitate the resuspension of sediments from the bottom of the lake into the water column. This is likely one cause of the reduced transparency in the lake. Sediments can be resuspended by wind and by motorboats. The elongate shape and the east-west orientation of Myers Lake give it a long wind fetch. By having a long, uninterrupted water surface for the wind to blow over, the mixing effect of the wind can extend into deeper water than on a lake with a shorter fetch. On Myers Lake this is likely the cause of turbulent resuspension of lake sediments. The extensive rooted plants help to mitigate this effect by stabilizing the sediments.

Motorboats should have restricted speeds in the areas of both lakes where the water is less than 10 feet (3 meters) deep. Research on shallow lakes has shown that a 50-hp outboard can resuspend fine clay sediments to a depth of 10 feet or 3 meters (Yousef et al., 1978).

LAKE AND WATERSHED RECOMMENDATIONS

This study identified several areas of concern. In the watershed, "hot spots" include the farm field east of Pine Road, the farm north of West 12th Road, the farm located in the northwest corner of the Pear and West 12th Roads intersection and the channel adjacent to Pear Road, and individual home sites. In-lake sampling pointed to excessive macrophyte growth, oxygen depletion in deeper water, ammonia production in the hypolimnion, and phosphorus release from the sediments as the major problems. Watershed modeling and in-lake sampling suggest that in-lake processes may be responsible for the bulk of problems observed in the two lakes. Consequently, the prioritized recommendations listed below are weighted toward in-lake treatments.

The priority list provides recommendations on how the lake associations should focus limited time and financial resources to achieve the most cost effective improvements to their lakes. While the list does recommend some larger projects first, this is not meant to minimize the effect that smaller watershed treatments may have on the health of Myers and Lawrence Lakes. Smaller watershed treatments such as those listed in item 4 are often more feasible based on cost and can be done while funds are raised to undertake some of the larger management techniques. The cooperative effort of lakeside residents in managing their own properties will have a positive impact on the health of the lakes over time.

Management efforts should be prioritized as follows:

1. A comprehensive aquatic plant management program should be developed for both lakes. The program should include a management technique or combination of techniques that will remove plant material from the lakes. Mechanical harvesting is the most commonly used techniques used to achieve this goal. Use of the Eurasian water milfoil weevil may be a possibility as well. This insect has had some success in controlling milfoil growth.

2. An alum treatment is recommended to prevent the release of phosphorus from the sediments. Internal loading was noted as the major contributor of phosphorus in both Myers and Lawrence

Lakes. An alum treatment will provide immediate treatment for this problem. Alum treatments are most effective when combined with efforts to decrease the input of phosphorus from other sources. Thus, the following two recommendations should not be ignored despite being assigned a lower priority.

3. The lake associations should work with watershed landowners and the NRCS to remove hot spot areas identified in this study from agricultural production, if possible, or establish filter strips in areas where nutrient and sediment runoff is most likely. Attempts have been made in the past to do this, but the effort should continue. Programs such as the Conservation Reserve Program may provide incentives to landowners. Alternatively, landowners may be willing to lease portions of the target lands to the lake associations. The DNR Division of Soil Conservation can provide technical and financial assistance to address agricultural land use issues through an application by the Marshall County Soil and Water Conservation District for watershed land treatment projects.

4. Lake associations should actively encourage the use of Best Management Practices by all current and future lakeshore residents. This includes the use of silt fences or other erosion control measures during the construction of new homes along the lakes' shorelines, reduction of fertilizer use on lawns, prohibiting the disposal of lawns wastes in the lakes, and promoting the installation of native plants along the shoreline. Concrete and sheet pile seawalls should be discouraged.

ADDITIONAL FUNDING

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Lake associations can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though specific BMPs (best management practices). As public awareness shifts towards watershed management these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake associations for watershed management.

Lake and River Enhancement Program (L.A.R.E.)

This is the program which funded this diagnostic study. L.A.R.E. is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the L.A.R.E. program may fund construction actions up to $100,000 for a specific project or $300,000 for all projects on a specific lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must be listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement.

Section 104(b)(3) Watershed Protection Grant

The Watershed Protection Grant is funded by the EPA and is administered locally by IDEM. This grant provides funding for the reduction and elimination of pollution within a targeted watershed. Priorities for funding include wetland/watershed protection demonstration projects, river corridor and wetland restoration projects, wetland conservation plans, assessment and monitoring plans, and wetland assessment models. The awarded amount can vary by project and there is a required 25% match.

Watershed Protection and Flood Prevention Program

The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture (USDA) and is administered by the local Natural Resource Conservation Service (NRCS). Funding targets a variety of watershed projects including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program

The Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency. CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas which have a high potential for degrading water quality under normal agricultural practices or areas that might make good habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Participants in the program receive up to 50% cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the local NRCS. WRP is subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish and other wildlife. The match for this program is on a 1:1 basis.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the local NRCS. This program provides support to landowners wanting to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

In addition to these federal and state funded grants there are several private organizations that provide grants to parties interested in maintaining or restoring the watershed where they live. For more information on private grant foundations visit the web site www.fdncenter.org.

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